Virginia Board of Housing and Community Development
CODES AND STANDARDS COMMITTEE
2024 CODE CHANGE CYCLE – BOOK 2, PART 2
May 11, 2026

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Tab 3 – USBC Proposals Recommended by the General Stakeholder Workgroup as Non-Consensus

Proposal No.	Proposal ID	Description	Page
96	B101.2(1)-24	Incorporates non-mandatory International Energy Conservation Code (IECC) Appendices CH, CI, CJ, RD, RI, RK, and RL, making them mandatory in Virginia.	Tab 3 – Page 1
		Staff Summary	Tab 3 – Page 3
97	B101.2(2)-24	Incorporates non-mandatory IECC Appendix RE, which requires electric vehicle ready and electric vehicle capable infrastructure for charging in new residential construction, and makes those provisions mandatory in Virginia.	Tab 3 – Page 5
		Staff Summary	Tab 3 – Page 11
98	B103.5-24	Removes the building official's authority to require certificates of functional design (public water supply systems, wastewater treatment and disposal systems, and solid waste facilities) prior to permit issuance.	Tab 3 – Page 13
		Staff Summary	Tab 3 – Page 14
99	B105.1-24	Clarifies that a building official's appointment is not "permanent" as they can be removed with cause.	Tab 3 – Page 15
		Staff Summary	Tab 3 – Page 16
100	B105.2.1-24	Deletes the minimum qualification requirements for technical assistants.	Tab 3 – Page 17
		Staff Summary	Tab 3 – Page 19
101	B107.1-24	Allows fees charged by building departments to exceed the actual cost of enforcement by up to 10 percent.	Tab 3 – Page 21
		Staff Summary	Tab 3 – Page 22
102	B109.2-24	Adds several exceptions to the provisions related to the review and approval of construction documents.	Tab 3 – Page 23
		Staff Summary	Tab 3 – Page 27

103	B109.3.1-24	Adds provisions for “deferred submittals”, similar to the provisions in the 2024 International Building Code.	Tab 3 – Page 29
		Staff Summary	Tab 3 – Page 32
104	B109.4-24	Adds time limitations for the review and approval of permit applications by the building official and requires the acceptance of third-party plan review reports from approved individuals or agencies when the timeframes cannot be met. Conflicts with B109.2-24.	Tab 3 – Page 33
		Staff Summary	Tab 3 – Page 44
105	B109.4(1)-24	Exempts construction documents for non-structural rooftop electrical equipment from plan review requirements when the permit application and plans are submitted by a licensed contractor or a Registered Design Professional. Requires permit issuance within two weeks of submission of the plans.	Tab 3 – Page 47
		Staff Summary	Tab 3 – Page 237
106	B113.6-24	Requires all written notices of defective work to reference the USBC section that serves as the basis for the defects. Currently, the USBC section is only required to be referenced upon request of the permit holder.	Tab 3 – Page 239
		Staff Summary	Tab 3 – Page 240
107	B113.7-24	Adds third-party inspection requirements specific to rooftop-mounted photovoltaic (PV) systems installed on one- and two-family dwellings and accessory structures.	Tab 3 – Page 243
		Staff Summary	Tab 3 – Page 245
108	B434-24	Adds new definition and requirements for bomb shelters.	Tab 3 – Page 247
		Staff Summary	Tab 3 – Page 335
109	B706.3-24	Allows fire walls to be constructed of any materials permitted by the building type of construction. Currently, they must be constructed out of noncombustible materials, except for buildings of Type V construction.	Tab 3 – Page 337
		Staff Summary	Tab 3 – Page 338
110	B903.2.1.2-24	Requires installation of an automatic sprinkler system in Group A-2 occupancies with an occupant load of 100 or more. Reducing the existing occupant load threshold from 299 to 99.	Tab 3 – Page 339
		Staff Summary	Tab 3 – Page 340

111	B906.1-24	Requires portable fire extinguishers in group R-2 occupancies and deletes an existing Virginia amendment which exempts groups A, B and E occupancies from the requirement to provide portable fire extinguishers, if the buildings are equipped throughout with quick response sprinklers (Companion SFPC Proposal FP906.1-24)	Tab 3 – Page 341
		Staff Summary	Tab 3 – Page 343
112	B907.2.1.1-24	Requires fire alarm systems in all Group A occupancies where ambient noise exceeds 105 dBA to reduce or turn off sources of ambient noise.	Tab 3 – Page 345
		Staff Summary	Tab 3 – Page 346
113	B907.5.2.1.2-24	Requires fire alarm systems in all Group A occupancies where ambient noise exceeds 105 dBA to reduce or turn off sources of ambient noise.	Tab 3 – Page 349
		Staff Summary	Tab 3 – Page 350
114	B917.1-24	Adds a new definition for “Emergency Management Coordinator” and requires mass notification risk analyses for certain university campuses to be approved by this coordinator.	Tab 3 – Page 353
		Staff Summary	Tab 3 – Page 357
115	B917.1.1-24	Adds a new definition for “Emergency Management Coordinator” and requires the building official to consult with this coordinator when a mass notification system is required.	Tab 3 – Page 359
		Staff Summary	Tab 3 – Page 362
116	B918.1-24	Changes the responsibility for installation of in-building two-way emergency responder communication coverage systems from the locality to the building owner.	Tab 3 – Page 365
		Staff Summary	Tab 3 – Page 368
117	B918.2-24	Adds requirements applicable to voluntary installations of in-building two-way emergency responder communication systems.	Tab 3 – Page 371
		Staff Summary	Tab 3 – Page 374
118	B1006.3.4(1)-24	Increases the maximum number of stories allowed for Group R-2 occupancies with a single exit, from three stories to six stories.	Tab 3 – Page 377
		Staff Summary	Tab 3 – Page 380

119	B1110.4-24	Expands the list of where adult changing stations are required, to include qualifying mercantile occupancies, state park campgrounds, state park visitor centers, and hospitals.	Tab 3 – Page 383
		Staff Summary	Tab 3 – Page 445
120	B1210.1.1-24	Requires installation of a hook, suitable for supporting medical equipment up to 10 lbs., near every toilet in public restrooms.	Tab 3 – Page 447
		Staff Summary	Tab 3 – Page 463
121	B2403.6-24	Adds requirements for bird-friendly design and construction to the VCC.	Tab 3 – Page 465
		Staff Summary	Tab 3 – Page 541
122	B3002.4-24	Exempts elevator cars in qualifying R-2 buildings six stories or less above grade plane from the requirement to accommodate ambulance stretchers.	Tab 3 – Page 543
		Staff Summary	Tab 3 – Page 545
123	B3104.1.1-24	Allows the use of American Association of State Highway and Transportation (AASHTO) Bridge Design Specifications as an alternative method of design and construction for pedestrian walkways.	Tab 3 – Page 547
		Staff Summary	Tab 3 – Page 548
124	B3105.2-24	Requires “canopies” to have frames of non-combustible material, fire-retardant-treated wood, heavy timber, or 1-hour construction, similar to awnings.	Tab 3 – Page 549
		Staff Summary	Tab 3 – Page 551
125	B3500-24	Requires buildings to comply with ASCE/SEI 24-2024 (2021 VCC and 2024 IBC reference ASCE/SEI 24-2014), and with ASCE/SEI 7-22 including Supplements 1 and 2 (2021 VCC and 2024 IBC reference ASCE/SEI 7-22 without Supplements 1 and 2).	Tab 3 – Page 553
		Staff Summary	Tab 3 – Page 661
126	RB301.2.1-24	Exempts removable vinyl or acrylic wind break panels at exterior balconies, decks, or porches under roofs from having to comply with the wind loading requirements.	Tab 3 – Page 663
		Staff Summary	Tab 3 – Page 666
127	RB324.7-24	Adds requirements for bird-friendly design and construction to the VRC.	Tab 3 – Page 669
		Staff Summary	Tab 3 – Page 750

128	RB408.4-24	Appears to intend to prohibit self-latching crawl space doors without an internal release.	Tab 3 – Page 753
		Staff Summary	Tab 3 – Page 755
129	EC-1301-24	Deletes all the existing Virginia amendments to the International Energy Conservation Code applicable to new commercial and residential construction.	Tab 3 – Page 757
		Staff Summary	Tab 3 – Page 766
130	EC-C402.1.6-24	Deletes the Virginia amendment in Appendix CD which currently may be used as an alternative to the building thermal envelope provisions of the code for Groups F, S, and U.	Tab 3 – Page 771
		Staff Summary	Tab 3 – Page 839
131	EC-C405.15-24	Deletes Section C405.15 (of the 2024 IECC) Renewable energy systems, including its subsections.	Tab 3 – Page 843
		Staff Summary	Tab 3 – Page 847
132	EC-C405.17-24	Adds new provisions for electric vehicle (EV) power transfer infrastructure and requires a minimum number of EV spaces, EV capable spaces and EV ready spaces based on occupancy group.	Tab 3 – Page 851
		Staff Summary	Tab 3 – Page 855
133	EC-C405.17(1)-24	Adds new provisions for electric vehicle (EV) power transfer infrastructure and requires a minimum number of EV spaces, EV capable spaces and EV ready spaces based on occupancy group.	Tab 3 – Page 859
		Staff Summary	Tab 3 – Page 874
134	EC-C409-24	Intends to add an additional energy compliance path for commercial and residential buildings based on Phius' software.	Tab 3 – Page 879
		Staff Summary	Tab 3 – Page 886
135	REC-R402.1.2-24	Increases wall insulation requirements across all three Virginia Climate Zones from R-15 (or R-13+1c.i.) to R-20 (or R-13+5c.i. or R-15+4c.i.). Adjusts U-factors accordingly.	Tab 3 – Page 891
		Staff Summary	Tab 3 – Page 908
136	REC-R402.1.2(1)-24	Maintains the 2021 VRC/VECC R-values and U-factors for ceiling insulation (R-49/U-0.026 in CZ 3, R-60/U-0.024 in CZs 4 & 5). The 2024 IECC reduced the R-values/increased U-factors to R-38/U-0.030 for CZ 3, and R-49/U-0.026 for CZs 4 & 5.	Tab 3 – Page 913

		Staff Summary	Tab 3 – Page 972
137	REC-R402.1.2(2)-24	Deletes the existing Virginia amendment to the wall insulation requirement and defaults to the 2024 IECC requirements (R-20 or R-13+5c.i. or R-15c.i. in CZ 3; and R-30 or R-20+5c.i. or R-13+10c.i. or R-20c.i. in CZs 4 & 5).	Tab 3 – Page 979
		Staff Summary	Tab 3 – Page 988
138	REC-R402.1.2(4)-24	Deletes the existing Virginia amendment to the wall insulation requirement and defaults to the 2024 IECC requirements (R-20 or R-13+5c.i. or R-15c.i. in CZ 3; and R-30 or R-20+5c.i. or R-13+10c.i. or R-20c.i. in CZs 4 & 5).	Tab 3 – Page 993
		Staff Summary	Tab 3 – Page 1053
139	REC-R402.4.1.2-24	Deletes the existing Virginia amendment related to air leakage testing and the allowable leakage rate, and defaults to the 2024 IECC requirements.	Tab 3 – Page 1057
		Staff Summary	Tab 3 – Page 1066
140	REC-R402.4.1.2(1)-24	Deletes the existing Virginia amendment related to air leakage testing and the allowable leakage rate, and defaults to the 2024 IECC requirements.	Tab 3 – Page 1073
		Staff Summary	Tab 3 – Page 1132
141	REC-R403.14-24	Requires the installation of a ceiling fan with variable speeds and reversible direction in each bedroom.	Tab 3 – Page 1139
		Staff Summary	Tab 3 – Page 1160
142	REC-R404.1-24	Reduces the required percentage of high-efficacy luminaires to a minimum of 90% of all permanently installed luminaires. (The 2021 VRC/VECC and the 2024 IECC require all permanently installed luminaires to be high-efficacy.)	Tab 3 – Page 1165
		Staff Summary	Tab 3 – Page 1166
143	REC-R404.2-24	Deletes the interior lighting control provisions that require the installation of automatic shutoff controls, such as occupancy sensors, vacancy sensors, door switches, programmable time switches, or countdown timers.	Tab 3 – Page 1169
		Staff Summary	Tab 3 – Page 1230
144	REC-R404.5-24	Requires one- and two-family dwellings and townhouses with designated parking to be provided with a minimum of one EV space, EV capable space or EV ready space; and R-2 occupancies with one space for 40 percent	Tab 3 – Page 1233

		of the dwelling units or automobile parking spaces, whichever is less.	
		Staff Summary	Tab 3 – Page 1247
145	REC-R404.5(1)-24	Requires one- and two-family dwellings and townhouses with designated parking to be provided with a minimum of one EV space, EV capable space or EV ready space; and R-2 occupancies with one space for 40 percent of the dwelling units or automobile parking spaces, whichever is less.	Tab 3 – Page 1253
		Staff Summary	Tab 3 – Page 1256
146	REC-R404.6-24	Incorporates the non-mandatory 2024 IECC Appendix NB (RB) Solar-Ready Provisions—Detached One- and Two-Family Dwellings and Townhouses, making the provisions mandatory in Virginia.	Tab 3 – Page 1261
		Staff Summary	Tab 3 – Page 1264
147	REC-R404.7-24	Incorporates the non-mandatory 2024 IECC Appendix NK (RK) Electric-Ready Residential Building Provisions, making the requirements mandatory in Virginia.	Tab 3 – Page 1267
		Staff Summary	Tab 3 – Page 1312
148	REC-R405.2-24	Removes the ability to use equipment trade-offs as part of the Simulated Building Performance compliance option.	Tab 3 – Page 1315
		Staff Summary	Tab 3 – Page 1319
149	REC-R405.2(1)-24	Requires that calculations for the Simulated Building Performance compliance option be based on annual site energy use, expressed in Btu or Btu per square foot of conditioned floor area, instead of annual energy cost.	Tab 3 – Page 1325
		Staff Summary	Tab 3 – Page 1343
150	REC-R405.2(2)-24	Changes the multiplier used to determine the proposed total building thermal envelope thermal conductance (TC) for compliance with the Simulated Building Performance method, reducing it from 1.15 to 1.08.	Tab 3 – Page 1347
		Staff Summary	Tab 3 – Page 1385
151	REC-R408.2.9-24	Deletes, without substitution, Section N1108.2.9 (R408.2.9), which is new to the 2024 IECC and allows a reduction in wall insulation when one of four qualifying conditions is met in Climate Zones 4 and 5.	Tab 3 – Page 1389
		Staff Summary	Tab 3 – Page 1390

152	E2701.1.1-24	Removes the option to provide provisions for the future installation of receptacles at an island or peninsular countertop or work surface, instead requiring receptacles to be installed at the time of construction.	Tab 3 – Page 1395
		Staff Summary	Tab 3 – Page 1400
153	E2701.1.1(1)-24	Limits the requirements for GFCI protection of basement receptacles to unfinished portions or areas of the basement not intended as habitable rooms. Currently, all basement receptacles must be GFCI protected.	Tab 3 – Page 1403
		Staff Summary	Tab 3 – Page 1405
154	M1109.3.2-24	Adds an exception from the ventilation shaft requirements when the refrigeration systems are serving only a single dwelling or sleeping unit and the refrigeration piping is continuous without fittings in the shaft.	Tab 3 – Page 1407
		Staff Summary	Tab 3 – Page 1411
155	M15-24	Updates ASHRAE 15 and ASHRAE 34 to their most current editions, the 2024 editions. The 2024 IMC references the 2022 editions.	Tab 3 – Page 1413
		Staff Summary	Tab 3 – Page 1414
156	P306.2.5-24	Limits the trench width for plastic sewer and DWV piping and requires the piping to be bedded in four inches of granular fill.	Tab 3 – Page 1415
		Staff Summary	Tab 3 – Page 1416
157	P306.3.1-24	Requires backfill for plastic sewer and DWV piping to be compacted to a minimum of 85 percent Proctor density and requires compaction testing to be performed by an approved third party and approved by the engineer of record.	Tab 3 – Page 1417
		Staff Summary	Tab 3 – Page 1418
158	RE3601.8-24	Requires the service disconnecting means for one-and two-family dwellings and townhouses to be installed in a readily accessible outdoor location. Installation of service disconnecting means indoors no longer allowed.	Tab 3 – Page 1421
		Staff Summary	Tab 3 – Page 1430
159	RE3901.4.2-24	Removes the option to provide provisions for the future installation of receptacles at an island or peninsular countertop or work surface, instead requiring receptacles to be installed at the time of construction.	Tab 3 – Page 1433

		Staff Summary	Tab 3 – Page 1434
160	RE3901.4.2(1)-24	Reinstates the 2017 NEC requirements for receptacles at island and peninsular countertops and work surfaces. Requires at least one receptacle to be installed at each island or peninsula and allows receptacles to be installed below the countertop.	Tab 3 – Page 1437
		Staff Summary	Tab 3 – Page 1440
161	RE3902.20-24	Removes the existing Virginia amendment that exempts branch circuits requiring GFCI protection from the AFCI protection requirements.	Tab 3 – Page 1441
		Staff Summary	Tab 3 – Page 1444
162	EB801.3-24	Allows the addition of one story atop an existing high-rise building without requiring a fire service access elevator, when the existing building cannot accommodate a fire service access elevator.	Tab 3 – Page 1447
		Staff Summary	Tab 3 – Page 1448
163	PM602.2(1)-24	Removes the heating and cooling date restrictions and sets a temperature range of not less than 65°F (18°C) and no more than 75°F (24°C) to be maintained throughout the year.	Tab 3 – Page 1451
		Staff Summary	Tab 3 – Page 1480

B101.2(1)-24

VCC: 101.2

Proponents: Joseph Wages, representing National Electrical Manufacturers Association (NEMA) (joseph.wages@nema.org)

2021 Virginia Construction Code

Revise as follows:

101.2 Incorporation by reference. Chapters 2 – 35 of the 2021 *International Building Code* ®, published by the International Code Council, Inc. (ICC), are adopted and incorporated by reference to be an enforceable part of the USBC. The term "IBC®" means the 2021 *International Building Code* , published by the International Code Council, Inc. Any codes and standards referenced in the IBC are also considered to be part of the incorporation by reference, except that such codes and standards are used only to the prescribed extent of each such reference. In addition, any provisions of the appendices of the IBC specifically identified to be part of the USBC are also considered to be part of the incorporation by reference. The following appendices to the 2024 International Energy Conservation Code® (IECC®) have been adopted and are a part of this code.

- Appendix CH Electric-Ready Commercial Building Provisions
- Appendix CI Demand Responsive Controls
- Appendix CJ Electrical Energy Storage System
- Appendix RD Electric Energy Storage Provisions
- Appendix RI On-Site Renewable Energy
- Appendix RK Electric-Ready Residential Building Provisions
- Appendix RL Renewable Energy Infrastructure

Notes:

1. The IBC references other International Codes and standards including the following major codes:

   2020 NFPA 70

   2021 *International Energy Conservation Code* ® (IECC ®)

   2021 *International Fuel Gas Code* ® (IFGC ®)

   2021 *International Mechanical Code* ® (IMC ®)

   2021 *International Plumbing Code* ® (IPC ®)

   2021 *International Residential Code* ® (IRC ®)

2. The IRC is applicable to the *construction* of detached one-family and two-family dwellings and townhouses as set out in Section 310 .

Reason Statement: The requirements outlined in Appendices CH, CI, and CJ of the 2024 IECC-C and Appendices RD, RI, RK, and RL were all approved by the ICC appointed Energy Code Consensus Committees by a two-thirds majority vote to be included in the Chapter 4 of the 2024 IECC as mandatory provisions of the code. While certain stakeholders submitted an appeal to ICC making the argument that these requirements are not within scope of the IECC, the ICC Board appointed Appeals Board stated in their final report dated March 4, 2024: "With respect to each of the nine appeals, the Appeals Board finds that the appellants have not demonstrated a material and significant irregularity of process or procedure, and therefore recommends the ICC Board of Directors deny each appeal." NEMA was opposed the final ruling of the ICC Board that relocated these important requirements to the appendices undermining the entire consensus process and recommendation of their own appeal board and therefore recommend the 2024 VECC officially adopt and incorporate these seven appendices as mandatory requirements.

Cost Impact: The code change proposal will increase the cost This proposal will increase the cost of compliance with the code, however, the requirements outlined in the seven adopted appendices have been shown to be cost effective by PNNL analysis during the 2024 IECC code development process.

It should be noted NEMA proposals are developed by a member consensus process where both our bylaws and federal regulations prohibit us from discussing prices, costs, and other financial details of electrical products.

B101.2(1)-24 – Staff Summary

Proponent: Joseph Wages, representing National Electrical Manufacturers Association (NEMA)

Brief Description: Incorporates non-mandatory International Energy Conservation Code (IECC) Appendices CH, CI, CJ, RD, RI, RK, and RL, making them mandatory in Virginia.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Second GSW Meeting — 10/03/2025

Support: William (Bill) Penniman Sierra Club, Virgina Chapter.

Opposition: Steve Shapiro, Apartment & Office Building Association of Metropolitan Washington (AOBA), Virginia Apartment and Management Association (VAMA); Andrew Clark Home Builders Association of Virginia (HBAV); Ron Clements Chesterfield County, Virginia Building and Code Officials Association (VBCOA) Admin and Existing Building Code Committees; Shahriar Amiri, Arlington County.

Discussion:

a) **Bryan Holland** – National Electrical Manufacturers Association (NEMA) provided an overview of the proposal.
   i. **Bill P** expressed support for the proposal based on the proponent's reason statement.
   ii. **Steve S** stated that the ICC board correctly kept these provisions in the appendices.
   iii. **Andrew C** noted that this creates a patchwork of enforcement across localities. ICC board deemed it outside of scope.
   iv. **Ron C** stated that the cost impact statement is inadequate. Further, this proposal makes requirements mandatory throughout Virginia and not optional for individual localities. Lastly, addressing a statement made by **Bryan H** in his opening remarks, that this proposal, according to an ICC Appeals Board ruling, meets the scope and intent of the 2021 and 2024 IECC. He notes that only the ICC Board of Directors can make determinations on scope and intent, not the ICC Appeals Board.
   v. **Shahriar A** expressed technical issues, noting the code doesn't specify how to install an Energy Storage System (ESS), only that one needs to be provided.

DHCD Staff Note: N/A

B101.2(2)-24

VCC: 101.2

Proponents: Angela Navarro, ALN Policy and Law, representing Virginia League of Conservation Voters

2021 Virginia Construction Code

Revise as follows:

101.2 Incorporation by reference. Chapters 2 – 35 of the 2021 *International Building Code* ®, published by the International Code Council, Inc. (ICC), are adopted and incorporated by reference to be an enforceable part of the USBC. The term "IBC®" means the 2021 *International Building Code* , published by the International Code Council, Inc. Any codes and standards referenced in the IBC are also considered to be part of the incorporation by reference, except that such codes and standards are used only to the prescribed extent of each such reference. In addition, any provisions of the appendices of the IBC specifically identified to be part of the USBC are also considered to be part of the incorporation by reference.
The following appendix to the 2024 International Energy Conservation Code® (IECC®) has been adopted and is a part of this code.

- Appendix RE Electric Vehicle Charging Infrastructure

Notes:

1. The IBC references other International Codes and standards including the following major codes:

   2020 NFPA 70

   2021 *International Energy Conservation Code* ® (IECC ®)

   2021 *International Fuel Gas Code* ® (IFGC ®)

   2021 *International Mechanical Code* ® (IMC ®)

   2021 *International Plumbing Code* ® (IPC ®)

   2021 *International Residential Code* ® (IRC ®)

2. The IRC is applicable to the *construction* of detached one-family and two-family dwellings and townhouses as set out in Section 310 .

Reason Statement: The proposal will incorporate the 2024 IECC Appendix RE into Virginia's residential building code. Appendix RE sets for the requirements for electric vehicle ready and electric vehicle capable infrastructure for electric vehicle charging in new residential construction.

The electric vehicle requirements in Appendix RE were originally planned for inclusion in the 2024 IECC, but were shifted to an appendix on appeal. As a result, in order for Virginia to adopt the electric vehicle charging infrastructure requirements, Virginia will need to add the text into the Virginia Construction Code for residential construction. This proposal does just that by adding a new Section R404.5 and N1104.5.

The proposal provides the option for new residential construction, defined as one and two household dwelling units and townhomes with attached or detached garages or other on-site private parking, to select among three levels of EV charging infrastructure. The first is EV Capable, which includes the raceway and basic infrastructure for future installation of equipment for plug-in power. The second is EV Ready, which is the basic infrastructure plus a branch circuit and outlet, junction box, or receptacle for future installation of equipment for plug-in power. The third level is the provision of the full electric vehicle charging infrastructure.

These three options provide maximum flexibility for the builders of new residential homes to select which level of investment to make while easing the burden for new homeowners when making the decision to install electric vehicle charging. The IECC commentary provides helpful guidance on this point, stating "EV capable spaces are the first step towards the preparation of future electric vehicle charging infrastructure. The raceways, electrical capacity, and panelboard placed and sized accordingly will ease future installations and reduce future costs."

As EV homeownership steadily increases in Virginia, these provisions are crucial to ensuring that home charging is not a barrier for future homeowners. The Virginia Auto Dealers Association released updated information on the growth of EV charging in 2025's first quarter, stating "sales of fully battery electric vehicles (BEVs), plug-in hybrids (PHEVs), and traditional hybrids all posted substantial gains compared to the same period in 2024. BEV sales rose by 18%, PHEVs surged 66% (though still account for a tiny slice of the market), and hybrid sales jumped 59%."

Electric vehicle adoption provides a number of economic and environmental benefits for Virginia. On the economic benefits, EV's can help households lower their monthly expenses on both fuel and vehicle maintenance. EV's can also drive broader economic benefits like job creation in manufacturing, such as the recent announcement from RBW for an EV manufacturing facility in Danville.

Electric vehicle adoption also drives significant environmental benefits. The primary benefit of EVs is decreasing the reliance on fossil fuels. As Virginia increases the amount of generation on the electric grid from carbon-free sources, the carbon reduction benefits will continue to grow over time. Further, because EVs don't burn gasoline, there are additional air pollution reduction benefits, including reductions in nitrogen oxides and particulate matter. Therefore, EVs deliver both climate reduction benefits and broader air quality benefits.

The proposal will help Virginians by removing barriers to EV adoption, which will deliver these important benefits to both households and the Commonwealth. By ensuring that home charging is not a costly barrier in Virginia going forward, this proposal provides a common-sense and practical step forward.

Cost Impact: The code change proposal will increase the cost The code change will have a cost impact, and that impact will depend on which of the three levels the residential homebuilder selects. The costs are small for EV Capable spaces and increase as the infrastructure level increases. However, the investment in making the dwelling unit EV-ready can increase its sale price and marketability due to growing buyer demand for electric vehicle convenience and sustainability. For example, according to a study in Nature Sustainability from researchers at Princeton and the University of Maryland, the increased availability of EV charging infrastructure within close proximity to the home increases home values by over $17,000 on average.

Attached Files

- **Appendix RE Electric Vehicle Charging Infrastructure.pdf**
  https://va.cdpaccess.com/proposal/1464/2266/files/download/1036/

Appendix RE Electric Vehicle Charging Infrastructure

Section RE101 Electric Vehicle Power Transfer

RE101.1 Definitions.

AUTOMOBILE PARKING SPACE.

A space within a *building* or private or public parking lot, exclusive of driveways, ramps, columns, office and work areas, for the parking of an automobile.

ELECTRIC VEHICLE (EV).

An automotive-type vehicle for on-road use, such as passenger automobiles, buses, trucks, vans, neighborhood electric vehicles and electric motorcycles, primarily powered by an electric motor that draws current from a building electrical service, *electric vehicle supply equipment* (EVSE), a rechargeable storage battery, a fuel cell, a photovoltaic array or another source of electric current.

ELECTRIC VEHICLE CAPABLE SPACE (EV CAPABLE SPACE).

A designated *automobile parking space* that is provided with electrical infrastructure such as, but not limited to, raceways, cables, electrical capacity, a panelboard or other electrical distribution equipment space necessary for the future installation of an *EVSE*.

ELECTRIC VEHICLE READY SPACE (EV READY SPACE).

An *automobile parking space* that is provided with a branch circuit and an outlet, junction box or receptacle that will support an installed *EVSE*.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE).

Equipment for plug-in power transfer, including ungrounded, grounded and equipment grounding conductors; electric vehicle connectors; attached plugs; any personal protection system; and all other fittings, devices, power outlets or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the *electric vehicle*.

ELECTRIC VEHICLE SUPPLY EQUIPMENT INSTALLED SPACE (EVSE SPACE).

An *automobile parking space* that is provided with a dedicated *EVSE* connection.

RE101.2 Electric vehicle power transfer infrastructure.

New residential *automobile parking spaces* for residential *buildings* shall be provided with *electric vehicle power* transfer infrastructure in accordance with Sections RE101.2.1 through RE101.2.5.

RE101.2.1 Quantity.

New one- and two-family dwellings and townhouses with a designated attached or detached garage or other on-site private parking provided adjacent to the *dwelling unit* shall be provided with one *EV capable*, *EV ready* or *EVSE* space per *dwelling unit*. R-2 occupancies or allocated parking for R-2 occupancies in mixed-use *buildings* shall be provided with an *EV capable space*, *EV ready space* or *EVSE* space for 40 percent of the *dwelling units* or *automobile parking spaces*, whichever is less.

Exceptions:

1. Where the local electric distribution entity certifies in writing that it is not able to provide 100 percent of the necessary distribution capacity within 2 years after the estimated certificate of occupancy date, the required *EV* charging infrastructure shall be reduced based on the available existing electric distribution capacity.
2. Where substantiation is *approved* that meeting the requirements of Section RE101.2.5 will alter the local utility infrastructure design requirements on the utility side of the meter so as to increase the utility side cost to the builder or developer by more than $450 per *dwelling unit*.

RE101.2.2 EV capable spaces.

Each *EV capable space* used to meet the requirements of Section RE101.2.1 shall comply with all of the following:

1. A continuous raceway or cable assembly shall be installed between a suitable panelboard or other on-site electrical distribution equipment and an enclosure or outlet located within 6 feet (1828 mm) of the *EV capable space*.
2. The installed raceway or cable assembly shall be sized and rated to supply a minimum circuit capacity in accordance with Section RE101.2.5.

3. The electrical distribution equipment to which the raceway or cable assembly connects shall have sufficient dedicated space and spare electrical capacity for a two-pole circuit breaker or set of fuses.
4. The electrical enclosure or outlet and the electrical distribution equipment directory shall be marked: “For future electric vehicle supply equipment (EVSE).”

RE101.2.3 EV ready spaces.

Each branch circuit serving *EV ready spaces* shall comply with all of the following:

1. Termination at an outlet or enclosure, located within 6 feet (1828 mm) of each *EV ready space* it serves and marked “For electric vehicle supply equipment (EVSE).”
2. Service by an electrical distribution system and circuit capacity in accordance with Section RE101.2.5.
3. Designation on the panelboard or other electrical distribution equipment directory as “For electric vehicle supply equipment (EVSE).”

RE101.2.4 EVSE spaces.

An installed *EVSE* with multiple output connections shall be permitted to serve multiple *EVSE spaces*. Each *EVSE* serving either a single *EVSE space* or multiple *EVSE spaces* shall comply with the following:

1. Be served by an electrical distribution system in accordance with Section RE101.2.5.
2. Have a nameplate charging capacity of not less than 6.2 kVA (or 30A at 208/240V) per *EVSE space* served. Where an *EVSE* serves three or more *EVSE spaces* and is controlled by an energy management system in accordance with Section RE101.2.5, the nameplate charging capacity shall be not less than 2.1 kVA per *EVSE space* served.
3. Be located within 6 feet (1828 mm) of each *EVSE space* it serves.
4. Be installed in accordance with NFPA 70 and be *listed* and *labeled* in accordance with UL 2202 or UL 2594.

RE101.2.5 Electrical distribution system capacity.

The branch circuits and electrical distribution system serving each *EV capable space*, *EV ready space* and *EVSE space* used to comply with Section RE101.2.1 shall comply with one of the following:

1. Sized for a calculated *EV* charging load of not less than 6.2 kVA per *EVSE*, *EV ready* or *EV capable space*. Where a circuit is shared or managed, it shall be in accordance with NFPA 70.
2. The capacity of the electrical distribution system and each branch circuit serving multiple *EVSE spaces*, *EV ready spaces* or *EV capable spaces* designed to be controlled by an energy management system in accordance with NFPA 70 shall be sized for a calculated *EV* charging load of not less than 2.1 kVA per space. Where an energy management system is used to control *EV* charging loads for the purposes of this section, it shall not be configured to turn off electrical power to *EVSE* or *EV ready spaces* used to comply with Section RE101.2.1.

Section RE102 Referenced Standards

RE102.1 General.

See Table RE102.1 for standards that are referenced in various sections of this appendix. Standards are listed by the standard identification with the effective date, standard title, and the section or sections of this appendix that reference the standard.

TABLE RE102.1 REFERENCED STANDARDS

STANDARD ACRONYM	STANDARD NAME	SECTIONS HEREIN REFERENCED
UL 2202—2009	*Electric Vehicle (EV) Charging System Equipment— with revisions through February 2018*	RE101.2.4
UL 2594—2016	*Standard for Electric Vehicle Supply Equipment*	RE101.2.4

B101.2(2)-24 – Staff Summary

Proponent: Angela Navarro, ALN Policy and Law, representing Virginia League of Conservation Voters

Brief Description: Incorporates non-mandatory IECC Appendix RE, which requires electric vehicle ready and electric vehicle capable infrastructure for charging in new residential construction, and makes those provisions mandatory in Virginia.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting — 01/06/2026

Support: Sydney Roberts, Southeast Energy Efficiency Alliance (SEEA); and Joseph Wages. Jr., NEMA.

Opposition: Steve Shapiro, Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA); Andrew Clark, Home Builders Association of Virginia (HBAV); Ron Clements, Chesterfield County and Virginia Building and Code Officials Association (VBCOA) Admin and Existing Building Code Committees; Mark Graver, City of Waynesboro and VBCOA Region III; Rick Hinson, American Council of Engineering Companies (ACEC); and Chris Reynolds, Atlantic Builders.

Discussion:

Angela Navarro provided an overview of the proposal.

a. **Sydney Roberts** expressed that decisions regarding electric vehicle ready infrastructure are typically made before there is a buyer for a home. The buyer will be facing a much higher cost to install equipment after the home is built. One point that was discussed yesterday was the system's impact. Including this in the code is important and initiates the conversation with the utility company. If the impact is unsurpassable with the utilities, then you get a pass.
b. **Steve Shapiro** reiterated that a work group should be formed to study all the issues around electric vehicle charging. Until such time when the workgroup is stood up, they are in opposition.
c. **Andrew Clark** highlighted that the cost drivers of electric vehicle ready infrastructure occur in the land development process. Utilities gold plate infrastructure requirements to accommodate new subdivisions or new multi-family buildings that are going to be equipped with electric vehicle charging stations. That is the opposite of what a lot of localities are trying to promote, which is walkable, denser communities, and smaller lot subdivisions that have less of an infrastructure impact and less of an impact on the natural environment around it. He suggested that the focus should be on trying to figure out how to get utilities

to right size their infrastructure requirements, so from a construction and land development perspective, we can incorporate these changes with minimal impact to the consumer and builder.

d. **Ron Clements** questioned whether electric vehicle charging stations in a parking lot are within the scope of the uniform statewide building code.
e. **Rick Hinson** expressed concern with dealing with fire from electric vehicles and how increasing costs affect affordable housing.
f. **Mark Graver** stated that the electric vehicle appendix has specific provisions that leave the owner out of the decision-making process. There are a lot of design decisions that go into putting in electric vehicle infrastructure and the appendix makes those decisions for you. **Mark G** believed that a code that narrows things down to only one pathway is not a good code.
g. **Angela N** brought up that utility companies can proactively plan for infrastructure to support a new community that might have higher load because of future electric vehicles. **Angela N** agreed with **Andrew C** that there needs to be communication with the State Corporation Commission around the question of whether the utilities are gold plating infrastructure.
h. **Chris Reynolds** seconded **Rick H's** concerns with affordability.
i. **Rick H** stated that he doesn't want to have to pay for something that he will never use and that the code is intended to create safety at the lowest cost.
j. **Shahriar Amiri,** Arlington County chimed in that at some point Virginia needs to move forward with this to some degree.

DHCD Staff Note: N/A

B103.5-24

VCC: 103.5

Proponents: David Beahm, representing Warren County (dbeahm@warrencountyva.gov)

2021 Virginia Construction Code

Revise as follows:

103.5 Functional design. The following criteria for functional design is in accordance with § 36-98 of the Code of Virginia. The USBC shall not supersede the regulations of other state agencies that require and govern the functional design and operation of *building* related activities not covered by the USBC, including (i) public water supply systems, (ii) waste water treatment and disposal systems, and (iii) solid waste facilities. Nor shall state agencies be prohibited from requiring, pursuant to other state law, that *buildings* and *equipment* be maintained in accordance with provisions of this ~~code. In addition, as established by this code, the building official may refuse to issue a permit until the applicant has supplied certificates of functional design approval from the appropriate state agency or agencies. For purposes of coordination, the *locality* may require reports to the building official by other departments or agencies indicating compliance with their regulations applicable to the functional design of a *building* or *structure* as a condition for issuance of a building permit or certificate of occupancy. Such reports shall be based upon review of the plans or inspection of the project as determined by the *locality*.~~ ~~All~~ code. All enforcement of these conditions shall not be the responsibility of the building official, but rather the agency imposing the condition.

> **Note:** Identified state agencies with functional design approval are listed in the “Related Laws Package,” which is available from *DHCD*.

Reason Statement: This section already indicates that the Building Official is not responsible for the enforcement of the regulations of other agencies. It also infers that the Building Official has no control over their approval process. It therefore doesn't make sense that the Building Official be required to or be able to hold issuing a building permit based on their regulations or conditions. The responsibility of imposing their requirements should solely be on their respective agency.

Cost Impact: The code change proposal will decrease the cost This will decrease the cost of construction in allowing the construction to begin as soon as approved without having to wait on other agencies that may be delaying approval due to their regulations. It will decrease any loan interest that may be in place or the return on investment being realized sooner when sold.

B103.5-24 – Staff Summary

Proponent: David Beahm, Warren County, Virginia Building and Code Officials Association (VBCOA)

Brief Description: Removes the building official's authority to require certificates of functional design (public water supply systems, wastewater treatment and disposal systems, and solid waste facilities) prior to permit issuance.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Second GSW Meeting — 10/03/2025 (carry over)

Third GSW Meeting — 01/06/2026

Support: None

Opposition: Michael Dellinger, Albemarle County and Virginia Building and Code Officials Association (VBCOA) Region IV; Ron Clements, Chesterfield County and VBCOA Admin and Existing Building Code Committees; and Doug Banks, representing himself.

Discussion:

David Beahm provided an overview of the proposal.

a. **Michael Dellinger** stated that keeping the section untouched is necessary.
b. **Ron Clements** agreed with **Michael D** and felt it takes away his ability to work with the agencies involved in functional design. **Ron C** also believed that there may be a legal conflict as state law requires them to coordinate with the health department for sewage disposal systems before issuing permits.
c. **Doug Banks** speaking for himself, voiced that the proposal appears to allow the beginning of construction without having the proper sanitary facilities.

DHCD Staff Note: N/A

B105.1-24

VCC: 105.1; VPMC: 104.4; SFPC: 105.1.1

Proponents: Ronald Clements, representing Chesterfield County Building Inspection Department (clementsro@chesterfield.gov)

2021 Virginia Construction Code

Revise as follows:

105.1 Appointment of building official. Every *local building department* shall have a building official as the executive official in charge of the department. The building official shall be appointed in a manner selected by the *local governing body*. ~~After permanent~~ After appointment, the building official shall not be removed from office except for cause after having been afforded a full opportunity to be heard on specific and relevant charges by and before the appointing authority. *DHCD* shall be notified by the appointing authority within 30 days of the appointment or release of ~~a permanent or acting~~ the building official.

Note: Building officials are subject to sanctions in accordance with the *VCS*.

2021 Virginia Property Maintenance Code

Revise as follows:

104.4 Local enforcing agency. In jurisdictions enforcing this code, the local governing body shall designate the agency within the local government responsible for such enforcement and appoint a *code official*. The local governing body may also utilize technical assistants to assist the *code official* in the enforcement of this code. ~~A permanently~~ The appointed *code official* shall not be removed from office except for cause after having been afforded a full opportunity to be heard on specific and relevant charges by and before the appointing authority. DHCD shall be notified by the appointing authority within 30 days of the appointment or release of ~~a permanent or acting~~ the *code official* and within 60 days after retaining or terminating a technical assistant.

Note: *Code officials* and technical assistants are subject to sanctions in accordance with the VCS.

2021 Virginia Statewide Fire Prevention Code

Revise as follows:

105.1.1 Appointment. The fire official shall be appointed in a manner selected by the *local government* having jurisdiction. After ~~permanent~~ appointment, the fire official shall not be removed from office except for cause after having been afforded a full opportunity to be heard on specific and relevant charges by and before the appointing authority.

Reason Statement: VBCOA supports this code change.

This code change is submitted on behalf of Delegate Delores Oats. During the 2024 legislative session, HB1092 was introduced by Delegate Oats that intended to limit building official appointments to 10 years and make it clear that they were not permanent appointments. The bill was submitted due to concerns that though the appointment code provision provides for the removal of the building official with cause, the statement that the appointment was permanent could make it difficult to remove the building official even with cause. The bill was left in committee after the 2024 session, and we offered to assist Delegate Oats with submission of a code change for the 2024 Virginia code cycle. This code change does not limit the appointment to 10 years but removes the word “permanent” from the third sentence, clarifying that the building official can be removed with cause. Since the building official can be removed with cause, it is not a permanent appointment in the sense that the building official is immune from removal. The maintenance and fire officials were added for consistency.

Cost Impact: The code change proposal will not increase or decrease the cost This provision does not impact the cost of construction.

B105.1-24 – Staff Summary

Proponent: Ronald Clements, representing Chesterfield County Building Inspection Department

Brief Description: The proposal clarifies that the building official can be removed with cause, after having been afforded a full opportunity to be heard on specific and relevant charges by and before the appointing authority, by deleting the word "permanent".

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

First GSW Meeting: 07/29/2025

Support: Andrew Milliken, Virginia Fire Services Board (VFSB); Ron Clements, Virginia Building and Code Officials Association (VBCOA) – Administrative Committee.

Opposition: David Beahm, representing self.

Discussion:

a. **Ron Clements** – Provides overview of proposal.
    i. **Sean Farrell** (Prince William County) – No objection to proposal. Did staff research when and how this language arrived in the code?
        1. **Florin Moldovan** (DHCD staff) – The proposal stands on its own merits and doesn't have any conflicts.
    ii. **David Beahm,** representing self – Has opposition. Building Official (BO) can be removed for cause, which was put in place to ensure there was a way to remove the BO if there is any issue. You can have an appointment for a 1-year time frame, and then that could be continuous. Right now, the code makes it clear that when you appoint the building official, the "Permanent" nature is so that they are removed from political actions and desires.
    iii. **Andrew Milliken** – VFSB supports this.
    iv. **Ron Clements** – VBCOA Administrative Committee supports.
    v. **David Beahm** – Clarifies he was speaking on behalf of himself.
    vi. Non-consensus.

DHCD Staff Note:

Per the proposal's reason statement, the code change was submitted on behalf of Delegate Delores Oats as a result of HB1092 (2024 GA Session). The bill was left in committee after the 2024 GA Session, and the proponent offered to assist Delegate Oats with submission of a code change proposal for the 2024 Virginia code development cycle.

B105.2.1-24

VCC: 105.2.1

Proponents: Kyle Kratzer, Fairfax County, representing VBCOA (kyle.kratzer@fairfaxcounty.gov)

2021 Virginia Construction Code

Delete without substitution:

~~**105.2.1 Qualifications of technical assistants.** A *technical assistant* shall have at least 3 years of experience and general knowledge in at least one of the following areas: building construction; building construction conceptual and administrative processes; building, fire or housing inspections; plumbing, electrical or mechanical trades; or fire protection, elevator or property maintenance work. Any combination of education and experience that would confer equivalent knowledge and ability, including high school technical training programs or college engineering, architecture, or construction degree programs, shall be deemed to satisfy this requirement. The *locality* may establish additional qualification requirements.~~

Reason Statement: Over the past decade, several changes have rendered this section unrealistic for all technical assistant positions. Significant pay disparities between the public and private sectors, along with the inclusion of permit technicians under the "technical assistant" designation, have made it increasingly difficult for code officials to fill these roles. As a result, recruiters are turning to non-traditional talent pools to meet staffing needs. Deleting this section shifts the responsibility for determining minimum qualifications to each locality, allowing for greater flexibility in hiring decisions. All technical assistants will still be required to demonstrate competence through certification, ensuring uniform enforcement capability regardless of individual experience or background.

The Virginia Building and Code Officials Association (VBCOA) supports this change.

Cost Impact: The code change proposal will not increase or decrease the cost This change should make it easier for departments to fill vacant positions and should have no bearing on the cost of construction.

VIRGINIA BUILDING & CODE OFFICIALS ASSOCIATION

April 6, 2026

Dear Members of the Board of Housing and Community Development,

I am writing on behalf of the Virginia Building and Code Officials Association (VBCOA) to express our strong support for the Board's ongoing code adoption process and to commend your continued commitment to ensuring a safe, resilient, and sustainable built environment across the Commonwealth.

The development and adoption of building and fire codes is a fundamental responsibility that directly impacts the health, safety, and welfare of our communities. Your deliberate and transparent approach, grounded in stakeholder input and technical expertise, ensures that Virginia's codes remain both effective and practical in their application.

We particularly appreciate the Board's continued engagement with local officials, industry professionals, and community stakeholders throughout this process. This collaborative effort strengthens the final code provisions and promotes consistency in enforcement across jurisdictions, ultimately benefiting citizens, businesses, and code officials alike.

As the built environment continues to evolve in response to emerging technologies, innovative construction methods, and increasing environmental challenges, your leadership is critical in striking the appropriate balance between safety, affordability, and innovation. Your work not only protects lives and property but also supports economic development and long-term community resilience across the Commonwealth.

VBCOA fully supports all consensus proposals as presented, as well as most non-consensus proposals. We respectfully request the Board's careful consideration of proposals B105.2.1-24 and REC-R402.1.2-24 as you finalize your decisions as VBCOA is in full support of both.

Thank you for your dedication, professionalism, and continued service to the Commonwealth of Virginia.

Respectfully,

Jason Laws, President
Virginia Building & Code Officials Association

B105.2.1-24 – Staff Summary

Proponent: Kyle Kratzer, Fairfax County, representing VBCOA

Brief Description: Deletes the minimum qualification requirements for technical assistants.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Second GSW Meeting — 10/03/2025

Support: Ron Clements, Chesterfield County and Virginia Building and Code Officials Association (VBCOA) Admin and Existing Building Code Committees; Corian Carney, York County, Independent Alliance of the Electrical Industry (IAEI) - Virginia Chapter; Dennis Hart, Virginia Plumbing and Mechanical Inspectors Association (VPMIA) and VBCOA PMG Code Committee.

Opposition: Mark Graver, City of Waynesboro, Builder, and VBCOA Region III

Discussion:

Kyle Kratzer provided an overview of the proposal.

i. **Mark Graver** (City of Waynesboro, Builder, VBCOA Region III) stated that qualifications are crucial for credibility and good stewardship.
ii. **Eric Mays** (Prince William County) responding to **Mark G,** cited examples of hires in Prince William County that would violate the current strict provisions but was in support.
iii. **Kyle K** explained that the proposed change arose because of a misunderstanding about the intent of the existing section concerning technical assistant qualifications. He further noted that recent high school technical training programs influenced changes to the provision's language and that under the current system, the "three years of experience" requirement was still being imposed even on individuals with a two-year degree, which created a barrier for qualified candidates. **Kyle K** emphasized that the intent here is to allow hiring of candidates who have an equivalent level of experience or education, not necessarily three years of direct experience. Lastly, he shared that Fairfax County has piloted an internship program where localities help interns gain the necessary "equivalent experience," and uses a tiered system to develop interns up to "qualified individual" status.
iv. **David Beahm** (Warren County, VBCOA) suggested a friendly amendment to remove "at least three years of…"

v. **Andrew Clark** [Home Builders Association of Virginia (HBAV)] asked if the intent was to address staffing; **Kyle K** confirmed.

vi. **Ron Clements** noted that Chesterfield County relies on “any combination of education and experience," and would have vacancies if the existing provisions were strictly enforced.

vii. **Sean Farrell** (Prince William County) expressed a need for correlation between the other regulations.

i. **Kyle K** noted that his intent is for correlation to occur and asked to discuss a compromise with opponents during the break.

Note: This proposal moved forward as non-consensus due to **Mark G’s** opposition

DHCD Staff Note: N/A

B107.1-24

VCC: 107.1

Proponents: David Beahm, representing Warren County (dbeahm@warrencountyva.gov)

2021 Virginia Construction Code

Revise as follows:

107.1 Authority for charging fees. In accordance with § 36-105 of the Code of Virginia, fees may be levied by the *local governing body* in order to defray the cost of enforcement of the ~~USBC.~~ USBCand shall not exceed the actual cost by more than 10%. With the exception of the levy collected pursuant to Section 107.2 , fees levied pursuant to this section shall be used only to support the functions of the *local building department.*

Note: See subsection D of § 36-105 of the Code of Virginia for rules for permit fees involving property with easements or liens.

Reason Statement: Many smaller jurisdictions struggle to have the appropriate resources to perform inspections to satisfy the general public and businesses. This increase would allow those, as well as all, to have a buffer to provide more personal, equipment (vehicles, computers, etc.) and software to assist. The increase will still be required to be solely used for the enforcement of the USBC and not to provide a revenue stream to the jurisdiction and would allow local jurisdictions to see the value in providing what is needed.

Cost Impact: The code change proposal will increase the cost It will increase the fees by 10% possibly if the jurisdiction chooses to.

B107.1-24 – Staff Summary

Proponent: David Beahm, representing Warren County

Brief Description: Allows fees charged by building departments to exceed the actual cost of enforcement by up to 10%.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Second GSW Meeting — 10/03/2025 (Carry Over)

Third GSW Meeting – 01/06/2026

Support: None

Opposition: Michael Dellinger, Albemarle County and Virginia Building and Code Officials Association (VBCOA); Ron Clements, Chesterfield County and VBCOA Admin and Existing Building Code Committees; Dan Willham, Fairfax County, VBCOA; and Shahriar Amiri, Arlington County.

Discussion:

David Beahm provided an overview of the proposal.

a. **Andrew Clark,** Home Builders Association of Virginia (HBAV) asked if the provision comes out of state law.
b. **David B** responded that it does.
c. **Andrew C** questioned if building code can get ahead of state law.
d. **Jeff Brown** (DHCD staff) replied that if a proposal goes to the Board that conflicts with state law, the proposal will be sent to the attorney general for them to weigh in and advise the Board if there is a potential conflict.
e. **Ron Clements** added that this proposal would require a bill since the code section specifically calls out the state law that this comes from.

DHCD Staff Note: N/A

B109.2-24

VCC: 109.2, 109.3, 109.4, 109.5, 109.6, 110.1, 113.3, 113.7.2, 116.1, 116.2

Proponents: David Beahm, representing Warren County (dbeahm@warrencountyva.gov)

2021 Virginia Construction Code

Revise as follows:

109.2 Site plan. When determined necessary by the building official, a site plan shall be submitted with the application for a permit. The site plan shall show to scale the size and location of all proposed *construction*, including any associated wells, septic tanks or drain fields. The site plan shall also show to scale the size and location of all existing *structures* on the site, the distances from lot lines to all proposed *construction*, the established street grades and the proposed finished grades. When determined necessary by the building official, the site plan shall contain the elevation of the lowest floor of any proposed *buildings*. The site plan shall also be drawn in accordance with an accurate boundary line survey. When the application for a permit is for demolition, the site plan shall show all *construction* to be demolished and the location and size of all *existing structures* that are to remain on the site.

Exceptions:

1. Site plansfor new one- and two-family dwellings shall not be required to include information for wells, septic tanks, drain fields, distances to lot lines, established street grades, elevation of the lowest floor or boundary lines per 109.4 Exception.
2. Site plans are generally not necessary for alterations, renovations, repairs or the installation of*equipment.*

Note: ~~Site plans are generally not necessary for alterations, renovations, repairs or the installation of *equipment*.~~

109.3 Engineering details. When determined necessary by the building official, *construction* documents shall include adequate detail of the structural, mechanical, plumbing or electrical components. Adequate detail may include computations, stress diagrams or other essential technical data and when proposed *buildings* are more than two stories in height, adequate detail may specifically be required to include where floor penetrations will be made for pipes, wires, conduits, and other components of the electrical, mechanical and plumbing systems and how such floor penetrations will be protected to maintain the required structural integrity or fire-resistance rating, or both. When dry floodproofing is provided, the engineering details shall include detail of the *walls*, floors, and flood shields designed to resist floodrelated loads, including the sealing of floor and *wall* penetrations. All engineered documents, including relevant computations, shall be sealed by the *RDP* responsible for the design.

Exception: For new one- and two- family dwellings per 109.4 Exception.

109.4 Examination of documents. The building official shall examine or cause to be examined all construction documents or site plans, or both, within a reasonable time after filing. If such documents or plans do not comply with the provisions of this code, the permit applicant shall be notified in writing of the reasons, which shall include any adverse construction document review comments or determinations that additional information or engineering details need to be submitted. The review of construction documents for new one- and two-family dwellings for determining compliance with the technical provisions of this code not relating to the site, location or soil conditions associated with the dwellings shall not be required when identical construction documents for identical dwellings have been previously approved in the same *locality* under the same edition of the code and such construction documents are on file with the *local building department*.

Exception: For new one- and two-family dwellings that applications for a permit have been made by an RDP or a properly licensed Class A contractor shall not require examination. Plans and documents shall be signed and sealed or signed and license number affixed respectively. All plans, documents and construction shall be in accordance with Section 103.1.

109.5 Approval of construction documents. The approval of construction documents shall be limited to only those items within the scope of the USBC. Either the word “Approved” shall be stamped on all required sets of approved construction documents or an equivalent endorsement in writing shall be provided. One set of the approved construction documents shall be retained for the records of

the *local building department* and one set shall be kept at the *building* site and shall be available to the building official at all reasonable times.

Exception: For new one- and two-family dwellings no "Approved" stamp or any other endorsement by the local building department shall be required when the application is presented per 109.4 Exception. However, one set of the documents indicated in 109.4 Exception shall be provided to the local building department for every building application.

109.6 Phased approval. The building official is authorized to issue a permit for the *construction* of foundations or any other part of a *building* or *structure* before the *construction* documents for the whole *building* or *structure* have been submitted, provided that adequate information and detailed statements have been filed complying with pertinent requirements of this code. The holder of such permit for the foundation or other parts of a *building* or *structure* shall proceed at the holder's own risk with the *building* operation and without assurance that a permit for the entire *structure* will be granted.

Note: Phased approval shall not apply to 109.4 Exception applications.

110.1 Approval and issuance of permits. The building official shall examine or cause to be examined all applications for permits or amendments to such applications within a reasonable time after filing. If the applications or amendments do not comply with the provisions of this code ~~or all pertinent laws and ordinances~~, the permit shall not be issued and the permit applicant shall be notified in writing of the reasons for not issuing the permit. If the application complies with the applicable requirements of this code, a permit shall be issued as soon as practicable. The issuance of permits shall not be delayed in an effort to control the pace of *construction* of new detached one- or two-family dwellings.

113.3 Minimum inspections. The following minimum inspections shall be conducted by the building official when applicable to the *construction* or permit:

1. Inspection of footing excavations and reinforcement material for concrete footings prior to the placement of concrete.
2. Inspection of foundation systems during phases of *construction* necessary to assure compliance with this code.
3. Inspection of preparatory work prior to the placement of concrete.
4. Inspection of structural members and fasteners prior to concealment.
5. Inspection of electrical, mechanical and plumbing materials, *equipment* and systems prior to concealment.
6. Inspection of energy conservation material prior to concealment.
7. Final inspection.

Note: For new one-and two-family dwellings, permitted under 109.4 Exception, the final inspections, when approved, shall be determined to have completed Section 116.1, Exception 3.

113.7.2 Qualifications. In determining third-party inspector qualifications, the building official may consider such items as *DHCD* inspector certification, other state or national certifications, state professional registrations, related experience, education and any other factors that would demonstrate competency and reliability to conduct inspections.

Exception: For new one- and two-family dwellings per 109.4 Exception that applications for a permit have been made by an RDP shall be approved as a third-party inspector on that permit for the allowed inspections within the written policy.

116.1 General; when to be issued. Prior to occupancy or *change of occupancy* of a *building* or *structure*, a certificate of occupancy shall be obtained in accordance with this section. The building official shall issue the certificate of occupancy within 5 *working days* after approval of the final inspection and when the *building* or *structure* or portion thereof is determined to be in compliance with this code and any pertinent laws or ordinances, or when otherwise entitled.

Exceptions:

1. A certificate of occupancy is not required for an accessory *structure* as defined in the IRC .

2. A new certificate of occupancy is not required for an addition to an existing Group R-5 *building* that already has a certificate of occupancy.
3. A certificate of occupancy shall be issued at the time of permit issuance when applied for per 109.4 Exception and will be determined in compliance when all final inspections have been approved.

116.2 Contents of certificate. A certificate of occupancy shall specify the following:

1. The edition of the USBC under which the permit is issued.
2. The group classification and occupancy in accordance with the provisions of Chapter 3 .
3. The type of *construction* as defined in Chapter 6 .
4. If an automatic sprinkler system is provided and whether or not such system was required.
5. Any special stipulations and conditions of the building permit and if any modifications were issued under the permit, there shall be a notation on the certificate that modifications were issued.
6. Group R-5 occupancies complying with Section R320.3 of the VRC shall have a notation of compliance with that section on the certificate.
7. Group R-5 109.4 Exception shall be indicated when applicable.

Reason Statement: Section 109.2 provides for the building official to have information and documentation provide to the department that we have no authority/responsibility/enforcement over per Section 103.5. This may be a consideration for large projects and anything that is subject to the VCC, but it should not affect a new one- and two-family dwelling that is being built by a Class A contractor who is the applicant or designed by an RDP.

Section 109.3 will need to have the exemption shown given that no department review is required when submitting this specific permit. If the plans are not subject to the Building Official's review, there is no need to have engineering details provided.

Section 109.4 requires the examination of plans and documents, which is needed in many cases, but for a new one- and two-family dwelling that is being applied for and built by a Class A contractor should not need to be reviewed, given that they know the code and are required to meet the code. If a code violation is found during inspections it will be up to the contractor to correct, or no passed inspection will be given. The permit will not be able to continue, and the certificate of occupancy will not be valid. In this case the contractor would be required to be the applicant and the contractor for the permit to be issued in this regard. If the applicant is an RDP the plans would be assumed to have designed per code and again, any violation found during inspections would need to be corrected or construction could not continue, and certificate of occupancy would not be valid. The exemption includes the indication that Section 103.1 would be required and that the individuals utilizing this exception would be fully responsible if they do not conform to the code during construction.

Section 109.5 requires that the plans be approved or an equivalent method, but if Section 109.4 were used the plans would not be required to be reviewed and would not be approved by the Building Official and no indication would be provided as such.

Section 109.6 would not be necessary for this Exception given the timing and would not be a possible method to start work without having the permit issued because the plans do not require review or Building Official approval.

Section 110.1 should only address what is under the authority of the Building Official and not indicate that permits can be held up by other laws or ordinances. This goes back to the proposal (Functional Design (1383)) and what authority the Building Official jurisdiction over.

Section 113.3 would indicate that only when final inspections for one- and two-family dwellings using 109.4 Exception have received all approved finals the certificate of occupancy would be approved. See additional portion of this proposal in Section 116.2.

Section 113.7.2 would allow the RDP that has made application can perform the inspections that are allowed under the jurisdictions written Third Party Policy without having to go through the qualification process for that permit only. Again, they would be attesting that they have completed the inspection per Section 103.1.

Section 116.1 would have the certificate of occupancy to be issued at the time the permit is issued, which would at that time have all of the information that is required to be on the certificate of occupancy and would only be in affect once all of the final inspections have been approved. There would be no waiting on obtaining a document when the required inspections have been approved. All other agencies

would be required to enforce their regulations and not the Building Official.

Section 116.2 would require a new item to be placed on the certificate of occupancy if 109.4 Exception is used, to indicate that while the Building Official has approved the required inspections the applicant can be fully held responsible for any code violation that is found given that they have taken on an expedited permit process and they are attesting to the fact that they know the code sufficiently enough to have undertaken this obligation.

Cost Impact: The code change proposal will decrease the cost This will decrease the cost of construction in allowing the construction to be completed as soon as all finals are approved not having to wait on a certificate of occupancy to be issued or other agencies delaying the issuance. It will decrease any loan interest that may be in place or the return on investment being realized sooner when sold.

B109.2-24 – Staff Summary

Proponent: David Beahm, representing Warren County

Brief Description: Adds several exceptions to the provisions related to the review and approval of construction documents.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Second GSW Meeting — 10/03/2025 (Carry Over)

Third GSW Meeting – 01/06/2026

Support: None

Opposition: Steve Shapiro, representing himself; Michael Dellinger, Albemarle County and Virginia Building and Code Officials (VBCOA) Region IV; Ron Clements, Chesterfield County and VBCOA Admin and Existing Building Code Committees; Andrew Milliken Stafford County Fire Marshal's Office, VFSB Codes and Standards Committee; and Shahriar Amiri, Arlington County.

Discussion:

David Beahm provided an overview of the proposal.

a. **Steve Shapiro** highlighted the following concerns for new one- and two- family dwellings:
   i. Section 109.2 Exception 1 - Eliminating the requirement for the elevation of the lowest floor from a Site Plan because this information is necessary in a special flood hazard area.
   ii. Section 109.4 Exception – Eliminating the requirement to review the plans.
   iii. Section 109.5 Exception – Same reason as Section 109.4 exception.
   iv. Section 113.7.2 Exception – RDP as an approved third-party inspector.
   v. Section 116.1 Exception 3 – Certificate of occupancy issued at the time of permit issuance.
b. **Andrew Milliken** pointed out that new Exception 2 in Section 109.2 uses the word "generally, and in the new exception in Section 109.4 a Class A contractor cannot be a design professional because the Class A contractor is not an individual and cannot stamp and sign drawings. **Andrew M** questioned what date do you put on the Certificate of Occupancy under new Exception 3 in Section 116.1. Is it the date when the permit is issued before the inspections are done, or after the final inspections have been approved?
c. **Ron Clements** indicated that VBCOA Admin Committee is also in opposition based on all the reasons already stated by others.

DHCD Staff Notes:

1. This proposal conflicts with proposal B109.4-24, which was also reviewed by stakeholders at the third GSW meeting on January 6, 2026, and received a Non-Consensus recommendation.
2. Portions of this proposal are similar to proposal B109.4(1)-24, which was also reviewed by stakeholders at the third GSW meeting on January 6, 2026, and received a Non-Consensus recommendation.

B109.3.1-24

VCC: 109.3.1 (New)

Proponents: Duru Meric, VA, representing Self (durumer@amazon.com)

2021 Virginia Construction Code

Add new text as follows:

109.3.1 Deferred submittals. Deferral of any submittal items shall have the prior approval of the building official. The registered design professional in responsible charge shall list the deferred submittals on the construction documents for review by the building official. Deferred submittals may include but are not limited to; fire protection systems, stairs, steel connections, steel joists, precast concrete, curtain walls, pre-engineered metal buildings, exterior platforms, cold form metal framing, awnings.
Documents for deferred submittal items may be submitted after the initial permit approval to the registered design professional in responsible charge who shall review them and forward them to the building official with a notation indicating that the deferred submittal documents have been reviewed and found to be in general conformance to the design of the buildings. The deferred submittal items shall not be installed until the deferred submittal documents have been approved by the building official.

Reason Statement: The 2024 International Building Code (IBC) Chapter 1 Section 107.3.4.1 includes deferred submittals requirements. These requirements are currently omitted from the Virginia Construction Code (VCC) Chapter 1, creating uncertainty in the deferred submittal timeline. The proposal intends to include clarification to VCC Chapter 1 Section 109.3 Engineering Details by the addition of Section 109.3.1 Deferred Submittal. This section is based on IBC Chapter 1 Section 107.3.1 Deferred Submittals. See attachment for IBC code reference. This proposal provides clarification on deferred submittal requirements.

Based on the established industry standards, the Architect of Record (AOR) provides performance and design criteria for the delegated design scope. The General Contractor (GC) secures a qualified and licensed design professional to prepare and seal the design. The AOR reviews the design for conformance post-permit issuance with the original design concept. This process is more efficient with time and budgets. Deferred submittals are no different than the established practice of foundations-only permit that Authority Having Jurisdictions (AHJ) issue all the time. Not defining the timeline creates unclarity in the process and causing deviation from industry standards by introducing additional front-end demands on the AOR, potentially impacting project schedules.

The lack of defined timeline impacts AHJ resources. It increases number of permit reviews and revisions causing hardship on AHJ capabilities to meet the increased demand of reviews within given timeline. The deferred design will go into additional series of revisions after securing the qualified and licensed design professional to prepare and seal design documents. This will cause another series of AHJ reviews and increase the challenges AHJs' ability to meet the review timelines.

As an example, it is an industry standard to design the structure of the building for the loads and reactions from deferred submittal items. During construction, the Structural Engineer of Record (SEOR) will then verify these assumptions with the drawings and calculations provided in the deferred submittal. For instance, with the case of stair design, the SEOR will show the loading and reaction assumptions from the stairs on their drawings but will not design the stair framing since this is done by a specialty designer with expertise in stair design. Typically, this specialty designer is the steel fabricator. This is the most efficient and safest process for the design of the stairs, as the steel fabricators that design and detail them are experts at designing stairs since this has been industry standard for so long. They are also the ones erecting the steel and have specific ways in which they want to assemble the stairs; deciding between which sections are assembled in the shop, and which are connected in the field. Because of this, the design of the stairs and stair connections will end up being changed during construction through RFIs from the steel fabricator regardless. Therefore, it is inefficient to have the SEOR go outside of their area of expertise and against industry norms to design something that will likely be changed during the delegated design process.

Adding the IBC Chapter 1 Section 107.3.4.1 Deferred Submittal and implementing clear deferred submittal requirements would streamline the process for all parties involved.

Cost Impact: The code change proposal will decrease the cost

Current unclarity in the deferred submittal requirements creates challenges in defining the design scope causing additional front-end demands on the Architect of Record (AOR). It also increases the amount of Authority Having Jurisdiction (AHJ) reviews and challenges AHJ capabilities to meet the increased review cycles within given timeline. Having clarity on the deferred submittal description and timeline will eliminate the additional review cycle processes.

Attached Files

- **IBC 2024 Chapter 107.3.4.1.jpg**
  https://va.cdpaccess.com/proposal/1543/2257/files/download/1022/

owner or the *owner*'s authorized agent to engage and designate on the *building permit* application a *registered design professional* who shall act as the *registered design professional in responsible charge*. If the circumstances require, the *owner* or the *owner's* authorized agent shall designate a substitute *registered design professional* in responsible charge who shall perform the duties required of the original *registered design professional in responsible charge*. The *building official* shall be notified in writing by the *owner* or the *owner*'s authorized agent if the *registered design professional in responsible charge* is changed or is unable to continue to perform the duties.

The *registered design professional in responsible charge* shall be responsible for reviewing and coordinating submittal documents prepared by others, including phased and *deferred submittal* items, for compatibility with the design of the building.

[A] 107.3.4.1: Deferred submittals.

Deferral of any submittal items shall have the prior approval of the *building official.* The *registered design professional in responsible charge* shall list the *deferred submittals* on the *construction documents* for review by the *building official*.

Documents for *deferred submittal* items shall be submitted to the *registered design professional in responsible charge* who shall review them and forward them to the *building official* with a notation indicating that the *deferred submittal* documents have been reviewed and found to be in general conformance to the design of the building. The *deferred submittal* items shall not be installed until the *deferred submittal* documents have been *approved* by the *building official*.

B109.3.1-24 – Staff Summary

Proponent: Duru Meric, representing Self

Brief Description: Adds provisions for "deferred submittals", similar to the provisions in the 2024 International Building Code.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting – 01/06/2026

Support: None

Opposition: Michael Dellinger, Albemarle County and Virginia Building and Code Officials Association (VBCOA) Region IV; Ron Clements, Chesterfield County and VBCOA Admin and Existing Building Code Committees; and Shahriar Amiri, representing himself.

Discussion:

Duru Meric provided an overview of the proposal and the associated floor modification.

a. **Ron Clements** questioned what happens when a Registered Design Professional (RDP) is not involved. There are several building types that Virginia allows to be designed without an RDP being involved. **Ron C** did not see the value in this proposal as it adds more confusion and probably adds more time than it saves.
b. **Duru M** responded that not having deferred submittal language is causing confusion on the authority having jurisdiction's (AHJ) side and the architect's side as to when those submittals should be submitted. The industry standard is to have them submitted by the general contractor or the licensed professionals preparing them, not by the Architect of Record (AOR) or the Structural Engineer of Record (SEOR).
c. **Shahriar Amiri** conceded that this is a real issue because of ambiguity and what is acceptable to submit to one jurisdiction should be good enough for all the others. However, **Shahariar A**, speaking for himself, was opposed to the term, "are not limited to", in the proposal.

DHCD Staff Note: N/A

B109.4-24

VCC: 109.4, 109.4.1, 109.4.2 (New), 109.4.3 (New), 109.4.3.1 (New), 109.4.3.2 (New), 109.4.4 (New), 116.1

Proponents: Paul Milde, representing Virginia House of Delegates, District 64

2021 Virginia Construction Code

Revise as follows:

109.4 Examination of documents. 109.4Examination of documents.
The building official shall examine or cause to be examined all construction documents or site plans, or both, within~~a reasonable time after filing. If such documents or plans do not comply with the provisions of this code, the permit applicant shall be notified in writing of the reasons, which shall include any adverse construction document review comments or determinations that additional information or engineering details need to be submitted. The review of construction documents for new one- and two-family dwellings for determining compliance with the technical provisions of this code not relating to the site, location or soil conditions associated with the dwellings shall not be required when identical construction documents for identical dwellings have been previously approved in the same *locality* under the same edition of the code and such construction documents are on file with the *local building department*.~~15 business days for Group R-5 structures and accessory structures to Group R-5, and within 25 business days for all other structures.

109.4.1 ~~Expedited construction document review~~Identical One- and Two-family Dwellings. The ~~building official may accept reports from an approved person or agency that the construction documents have been examined and conform to the requirements of the USBC and may establish requirements for the person or agency submitting such reports. In addition, where such reports have been submitted, the building official may expedite the issuance of the permit.~~review of construction documents for new one- and two-family dwellings for determining compliance with the technical provisions of this code not relating to the site, location or soil conditions associated with the dwellings shall not be required when identical construction documents for identical dwellings have been previously approved in the same locality under the same edition of the code and such construction documents are on file with the local building department.

Add new text as follows:

109.4.2 Concurrent review. When the issuance of permits are contingent upon review and approval by other state agencies that require and govern the functional design and operation of building related activities not covered by the USBC, including (i) public water supply systems, (ii) waste water treatment and disposal systems, and (iii) solid waste facilities, the examination of construction documents by the building official shall not be delayed until such approval is granted by the state agency.

109.4.3 Expedited construction review. The building official may accept reports from an approved individual or agency that the construction documents have been examined and conform to the requirements of the USBC. Such individual or agency shall be approved in accordance with Section 109.4.3.2. Where such reports have been submitted, the building official may expedite the issuance of the permit.

109.4.3.1 Third-party construction document examination. Under circumstances where the building official is unable to examine, or cause to be examined, the construction documents within the timeframe set forth in Section 109.4, or an agreed upon date, the building official shall accept third-party plan review reports from individuals or agencies approved in accordance with the building official's written policy required by Section 109.4.3.2. The building official shall approve such reports unless there is cause for rejection. Failure to approve a report shall be in writing within five working days of receiving it stating the reason for the rejection. The building official shall notify the permit applicant of their inability to comply with the timeframe set forth in Section 109.4 within five working days after filing.

109.4.3.2 Third-party plans examiners. Each building official charged with the enforcement of the USBC shall have a written policy establishing the minimum acceptable qualifications for approval of third-party plans examiners. The policy shall include the format and time frame required for submission of reports, any prequalification or preapproval requirements before conducting a third-party plan review, and any other requirements and procedures established by the building official.

109.4.4 Notification. Upon completion of construction documents examination by the building official, the permit applicant shall be notified in writing, via electronic mail, of the status of the project and required next steps.

Exception: If the permit applicant does not have a valid email address, notification via telephone or mutually agreed upon method is acceptable.

If the construction documents do not comply with the provisions of this code, the permit applicant shall be notified in writing, via electronic mail, of the reasons, which shall include any adverse construction document review comments or determinations that additional information or engineering details need to be submitted.

Exception: If the permit applicant does not have a valid email address, notification via a mutually agreed upon method is acceptable.

Revise as follows:

116.1 General; when to be issued. Prior to occupancy or *change of occupancy* of a *building* or *structure*, a certificate of occupancy shall be obtained in accordance with this section. The building official shall issue the certificate of occupancy within ~~5~~ 2 *working days* after approval of the final inspection and when the *building* or *structure* or portion thereof is determined to be in compliance with this code and any pertinent laws or ordinances, or when otherwise entitled.

Exceptions:

1. A certificate of occupancy is not required for an accessory *structure* as defined in the IRC .
2. A new certificate of occupancy is not required for an addition to an existing Group R-5 *building* that already has a certificate of occupancy.

Reason Statement: Summary of changes:

109.4 - "A reasonable time" was replaced with set times. The balance of existing provisions set forth by the Section have been relocated to other sections.

109.4.1 - These are existing provisions that have been relocated from Section 109.4 to their own subsection to provide clarity and highlight the importance of the proposed timeframes in Section 109.4.

109.4.2 - New provisions have been added to address concerns related to building departments not performing technical review of construction documents prior to receiving approval from the Virginia Department of Health.

109.4.3 - "Person" has been replaced with "individual" for consistency with terminology used in Section 113.7.

109.4.3.1 - Newly proposed Section intended to allow for third-party plan review if the local building departments cannot comply with the newly proposed timeframe for construction document review.

109.4.3.2 - Newly proposed Section, modeled after existing requirements for third-party inspectors (see Section 113.7.1) intended to set the framework for establishing policies for third-party plan reviewers.

109.4.4 - Newly proposed requirements intended to eliminate the need for contractors to constantly monitor permit status due to lack of notification from building departments. The exceptions have been added to account for isolated cases where the permit applicant may not have an email address nor the means to create or utilize one.

116.1 - Revised the timeframe for the issuance of the Certificate of Occupancy from 5 working days to 2 working days.

Summary of June 25th Expediting Permits and COs Study Group (See Attached)

Cost Impact: The code change proposal will not increase or decrease the cost "The code change proposal will not increase or decrease the cost" option was selected.

Attached Files

- **20250625-expediting-permits-and-cos-sg-meeting-summary.pdf**
  https://va.cdpaccess.com/proposal/1397/2029/files/download/948/

Expediting Permits and COs Study Group
First Meeting Summary
Date: June 25, 2025
Location: Virginia Housing Center
Time: 10:02 AM – 1:24 PM

Attendees:

VA Department of Housing and Community Development (DHCD) Staff:

- **Jeff Brown** – Deputy Director, Division of Building and Fire Regulation
- **Florin Moldovan** – Code and Regulation Specialist, State Building Codes Office
- **Paul Messplay** – Code and Regulation Specialist, State Building Codes Office
- **Chris Scott** – Code and Regulation Specialist, State Building Codes Office
- **Chase Sawyer** – Policy and Legislative Services Manager

Study Group Members:

- **Cory Carney** – Independent Alliance of the Electrical Industry, VA Chapter
- **Chris Reynolds** – Atlantic Builders
- **Ron Clements** – Local Building Official
- **Michelle Gowdy** – Virginia Municipal League
- **Amanda Spittle** – Virginia Building and Code Officials Association
- **Andrew Clark** – Home Builders Association of Virginia

Interested Parties

- **Delegate Paul Milde** – Virginia House of Delegates 2025, 64th District
- **Nicholas Bowles** – Nottoway County, Building Official

Purpose:

The Expediting Permits and Certificates of Occupancy (CO) Study Group (the group) convened Virginia DHCD staff, code enforcement professionals, homebuilders, and local government stakeholders to discuss processes related to the issuance of building permits and COs with a focus on identifying opportunities for streamlining the review and issuance of such.

Key topics included current regulatory timelines, delays caused by staffing and procedural issues, and the feasibility of establishing clearer standards for review times and third-party involvement. The group explored options to streamline permit and CO issuance, reduce costs, and enhance coordination among agencies, with a focus on developing code change proposals to address delays and administrative bottlenecks.

Background:

- Jeff – Provided background on the study group's formation, including the legislation (HB 2682) that preempted the group's formation.
- Del. Milde – Acknowledged that he is unsure if this study group is the appropriate vehicle to handle the issue of expediting permits and COs. Delegate Milde also expressed familiarity with Stafford County, a rapidly growing top-ten county with significant commercial development. He noted that both commercial and residential builders are experiencing increasing delays, which lead to higher costs for applicants. Many small, mom-and-pop builders struggle to understand the complex code, further prolonging the process. Milde questioned whether current timelines are mandated by county or state law, and if the building code can specify such timelines, highlighting that life safety is the primary goal. He asked if this is the appropriate place to incorporate timelines.
- Jeff clarified that the regulations do include some timing provisions. For example, there are timeline limitations on issuing Certificates of Occupancy (CO) and response times for inspections. Specifically, suppose the building official is unable to perform an inspection within two working days. In that case, the permit holder can hire a third-party inspector and submit that report for review and approval by the building official. Delegate Milde confirmed Jeff was referring to the Virginia Uniform Statewide Building Code, which Jeff affirmed.
- Discussion about whether current timelines are mandated by law or policy, and how local staffing issues influence permit issuance times.

Key Discussion Points:

Permit Timelines and Administrative Processes

The group discussed existing regulatory timelines, such as the 5-day timeframe for issuing COs, and the challenges associated with actual review and inspection durations.

Five-Day Timeline Discussion:

- Jeff - Brings attention to Section 116.1 of the USBC, which requires the issuance of COs within five working days.
- Chris R – In the past, he has been able to get COs in 1 day. The reality is that five working days, starting on a Friday afternoon, mean the clock begins Monday morning. So, three days have already passed. Then we go through five working

days and get the CO on Friday, which means we can't close until Monday. The carrying costs are $1,500-$2,000 over that timeline.

Plan Review Duration Discussion:

- Chris R – Trying to establish a precise timeline for issuing permits isn't reasonable. Instead, he suggested focusing on defining what constitutes a reasonable time for at least an initial review, given the significant evolution of the permitting process, from generic house plans covering various elevations to highly specific, engineered designs. He pointed out that most work is now done by engineers, making it unfair to set a fixed timeline for permit issuance. Additionally, some municipalities will not start the review until they receive the health permit, which can cause a month-long delay between localities. In practice, the permit isn't issued until the health permit is obtained, and he questioned why concurrent reviews can't be performed to speed up the process.
- ::Short break until 11:17::
- Jeff – (Reopened the discussion.)
- Del. Milde – If the group is interested in defining a reasonable timeline or working within the framework of Section 109.4 to add some boundaries, that might not be the purpose of this group. (He suggested that it could be simplified by establishing timelines for localities with a population size above a certain threshold.)
- Andrew – (Has some hesitation about setting size limits, noting that doing so could lead to frequent code change proposals every cycle. He agreed there is value in considering a "reasonable time," but the second sentence of the section might allow for some flexibility with re-reviews. He suggests that the locality should be required to notify the applicant within a certain number of days. Asks Ron how often people resubmit plans.)
- Ron – It's common for builders to have six or seven inspections, and that multiple re-reviews happen on plan review as well. The main challenge is defining what constitutes a "reasonable" review time.
- Andrew – (Clarified he was referring to the provision after that, regarding notification of plan deficiencies.)
- Chris R – What we're seeing is that we have to proactively seek and find that information instead of it being shared with us – we have staff who monitor it daily.
- Andrew – Just throwing out ideas. The applicant knows that within a certain number of days, they will be informed if the response is not sufficient.

- Ron – For (Chesterfield) we used to have a gatekeeping process for commercial permits. Applicants would go to the office, and a plan reviewer would look at the plans to ensure all necessary information was included before we accepted them. We moved away from doing a preliminary review because it didn't provide a good return on investment of time.
    i. Ron – Andrew, you want to set a timeframe for the initial review, but not for subsequent reviews, correct?
    ii. Andrew – Yes. It seems to provide some benefit for both the locality and the applicant.
    iii. Del. Milde – And your idea of how quickly you'd be notified of deficiencies?
    iv. Andrew – Yes, the second sentence—effectively. We should work on this offline.
    v. Chris R – Review processes mainly depend on the system used by each county. Some localities provide formal notifications; others we don't receive any notifications at all.
    vi. Del. Milde – Delays often start after the quality control (QC) process. The challenge is that we don't always know where reviewers are, and different departments are trying to work on it. The technical review is particularly hard to pin down.
    vii. Jeff – From my experience as a plan reviewer and building official, the type of drawing and the type of house significantly affects the review time.

Staffing, Resources, and Best Practices

Staffing shortages, high turnover, and resource limitations are major factors affecting review times.

- Amanda – Staffing has been an issue, but not in Prince William, where we have project management and proactive project oversight. I think smaller localities may be struggling more, especially when they're experiencing rapid growth.
- Del. Milde – Labor shortages and high turnover are definitely challenges. It's also about how they prioritize their customers. One idea I have is to develop a tailored list specific to each project. I've seen code that suggests this should be done, but it has never been mandated. I really like that idea.

Some localities implement proactive project management and tailored checklists to expedite reviews, especially for large commercial projects.

- Ron – Typically, about a month out from the end of a commercial project, our commercial inspector reaches out to the contractor to update them on what's outstanding. This includes planning and zoning, environmental engineering, utilities, and coordinating all relevant parties. However, I don't understand why it takes five days to issue the CO after all of that is completed.

  ::Separate Discussion::

- Ron – What I was referencing was larger commercial projects, full buildings. Our commercial inspection chief keeps an eye on those jobs, and once they're close to Certificate of Occupancy (CO), he pulls together all outstanding issues.
- Del. Milde – What's the criteria?
- Ron – That would be difficult; it involves a lot of judgment calls. Take the "two-day" concept and apply it to plan review—start with that as a trial balloon. The challenge is, what do you replace the two days with? Thirty days?
- Ron – For some localities, it won't be an issue. I recommend identifying those where it might be problematic.

Third-Party Plan Review and Inspection

The group examined the possibility of formalizing third-party review processes, with considerations around vetting, approval, and how to ensure quality control.

- Del. Milde – Has anyone ever considered using a third-party review?
- Cory – Refer to 109.4.1.
- Del. Milde – It says "may." I guess that's the keyword.
- Cory – We still have to conduct a review.
- Del. Milde – Do you still need to review a third-party submission even if it's "approved"?
- Ron – We can accept third-party reviews. It's really up to the building official's authority to set parameters and decide what aspects they want to QC.
- Andrew – Is there interest in requiring at least a baseline standard of third-party review in localities?
- Del. Milde – A pre-approved list of engineers?
- Chris R – (Shares his experience with the third-party plan review policy in Spotsylvania.)

- Amanda – That can cut review time in half because the engineer takes responsibility.
- Florin – Spotsylvania had a program specifically for expediting review that required sealing by an RDP. It was intended to be a quick review of the site-specific documents only, such as soil compaction reports and HVAC design worksheets. They also had a master file program where the contractor submitted a file with all the different designs and options for a specific house. Once the plan review was completed on that, any subsequent permits for that house would only require site-specific review. Section 109.4.1 is used by localities and facilitates some of that process.
- Cory – Implementing processes like that across the board would be mutually beneficial.

There was debate about whether to change "may" to "shall" in code language to mandate third-party reviews, and how to implement qualified lists of engineers or reviewers.

- Del. Milde – So, just change "may" to "shall," and we're good.
- Ron – In Chesterfield, that would be problematic.
- Florin – (Shares Section 113.7 on the screen, for context.)
- Jeff – Clarified that "accept" in Section 113.7 does not mean the building department must "approve" an inspection report submitted by a third-party, and added that some local building department third-party policies include a list of approved third-party agencies, ensuring the reports they are accepting are from third-parties they have vetted.
- Del. Milde – If it's an approved engineer, you still have to review what they're doing. You can't just blindly accept their work.
- Jeff – If there's no vetting process in place —for example, with plan review—more items might be missed during plan review and if issues are identified during inspections, corrections may be more costly and cause increased delays.
- Del. Milde – The only way that approach would meet our goal is if, along with that, there's a prescriptive, shortened timeline. If you're using an approved third-party review, then you only have a certain number of days to approve that third-party's technical review.

Defining "Reasonable Time" & Timeline Standards

A key challenge is establishing what constitutes a "reasonable" review and approval timeline, given the diversity of localities and project types.

- Florin – (Shares Section 109.4 on the screen, for context, which states "within a reasonable time.")

- Chris R – That is a very grey area. We build a lot of well and septic homes, and their process is different. Everything is engineered and done by onsite soil engineers, who have a very defined timeline—21 days. If they can't complete their review within that period, it's deemed approved. It would be helpful to have some focus on this—I'm not suggesting we replicate the health department, but something more clearly defined. The process varies so widely and has become so unpredictable that the most predictable part is actually building the home and structure.
- Andrew – Is there some sort of reasonable timeline for the building official?
- Cory – Mandating a statewide timeline is incredibly unwise. I suggest each locality develop its own timelines to guarantee it returns plans within a certain number of working days.
- Andrew – There has to be some timeline.
- Michelle – Any specific timeline will be discussed later.
- Chris R – Trying to set a strict timeline for permit issuance isn't reasonable. It makes more sense to define what constitutes a reasonable time for at least an initial review because the permitting process has evolved significantly. It used to be a generic house plan that covered all elevations, but now everything is highly specific and engineered. All work is done by engineers. It's not fair to set a fixed timeline for permit issuance. Some municipalities won't even start reviewing until they receive the health permit, which can be a month apart between localities. In reality, it doesn't matter because the permit isn't issued until the health permit is obtained. I don't understand why concurrent reviews can't be done.
- [Short break]
- Jeff – (Opens the discussion back up.)
- Del. Milde – If this group is interested in how to define a reasonable time, or in working with the language in Section 109.4 to add some boundaries, then that's not the purpose of this group. It would be helpful to add specific timelines for localities of a certain population size or greater to simplify the process.
- Andrew – (Has some hesitation about setting a size limit.) Every code cycle, we'll likely get proposals like this. There's value in considering a "reasonable time," but the second sentence of Section 109.4 might allow for re-reviews.

Pertinent Laws and Ordinances & Certificate of Occupancy (CO) Delays

Discussions focused on how other laws (zoning, landscaping, etc.) can delay CO issuance beyond the building code requirements.

Potential revisions to code language (e.g., removing "all pertinent laws and ordinances" or clarifying language) were considered to reduce unnecessary delays.

- Ron – What this is telling us—Section 116.1—is that the building official, beyond verifying compliance with the building code, must also ensure compliance with other laws and ordinances. The term "pertinent" was included for a reason. Planning departments might consider landscaping plans pertinent. In this context, is "pertinent" appropriate? It could include everything from screening dumpsters, striping parking lots, to paving versus gravel. Most planning and zoning departments will consider anything on the site plan as "pertinent," and that could be grounds to hold up the CO.
- Michelle – How do they enforce landscaping if it's not part of the building permit?
- Amanda – They hold up escrow.
- Ron – Since it's an ordinance, if the owner doesn't comply, I'm not in compliance with those ordinances. Occasionally, localities will issue a temporary CO.
- Jeff – I am aware of many instances where the reason for not issuing a CO is related to landscaping and other items that are not related to being able to safely use the building. I am not sure that is the intent of the code
- Jeff – If the USBC were updated to remove the building official from being the gatekeeper and the building official were no longer required to deny issuance of a CO on behalf of other departments and agencies, it would not prevent those other departments from enforcing their requirements. It would also not impact existing state laws, like those regarding health department approvals, that specifically address when a building official may or may not issue a CO.
- Florin – If you add a period after "code" in Section 116.1 and strike everything afterward, that addresses the issue.
- Cory – You can change the language, but the ordinance issues still prohibit issuance of the CO. Stopping right after "code" makes it clear.
- Florin – The way it's written, an argument could be made that the building code is used as an enforcement mechanism for laws or ordinances outside the scope of the building code.
- Ron – (Agrees. He thinks that for zoning and land use, "pertinent" is quite broad, similar to "reasonable.") When should we hold up the issuance of a CO beyond the building code? (He doesn't have a specific answer, but zoning is a clear example.)
- Jeff – If the words "all pertinent laws and ordinances," were removed, would the building official still have some discretion in issuing a CO if, for example, the final inspection passed, but an approved plat was not in place?
- Ron – If you remove it, all you're left with is the building code, and that would give the permit-issuing authority the ability to issue a permit without regard to zoning or other laws.

Proposal Development

The group discussed developing proposals for clearer timelines, third-party review standards, and administrative procedures.

Future actions include drafting code change proposals, circulating proposals for feedback, and possibly convening additional meetings or working via email.

Conclusion & Next Steps

The group agreed to take the lead on developing specific language and proposals related to timelines, third-party reviews, and administrative procedures.

They emphasized flexibility in approach, with opportunities for further discussion and refinement before formal adoption or legislative change.

Adjourned: 1:24pm

B109.4-24 – Staff Summary

Proponent: Delegate Paul Milde, Virginia House of Delegates 2025, 64th District

Brief Description: Adds time limitations for the review and approval of permit applications by the building official and requires the acceptance of third-party plan review reports from approved individuals or agencies when the timeframes cannot be met.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

See DHCD Staff Notes below.

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Second GSW Meeting — 10/03/2025 (Carry Over)

See DHCD Staff Notes below.

Third GSW Meeting – 01/06/2026

Support: Chris Reynolds, Atlantic Builders; Andrew Milliken, representing himself; and Andrew Clark, Home Builders Association of Virginia (HBAV).

Opposition: Ron Clements, Chesterfield County and Virginia Building and Code Officials Association (VBCOA) Admin and Existing Building Code Committees; Michael Dellinger, Albemarle County and VBCOA Region IV; Rick Hinson, American Council of Engineering Companies (ACEC); Shahriar Amiri, Arlington County; Mark Graver, City of Waynesboro and VBCOA Region III; Dan Willham, Fairfax County and VBCOA; Gregg Fields, City of Alexandria; and David Beahm, Warren County and VBCOA.

Discussion:

I. **Delegate Milde** provided an overview of the proposal.

Jeff Brown (DHCD staff) noted that a Study Group on Expediting Permits and Certificates of Occupancy was convened during this code development cycle. The group's discussions and feedback directly informed the development of this proposal.

a. **Chris Reynolds** voiced to the group to consider assigning timelines, not just for the benefit of the builder but also the consumer.
b. **Andrew Milliken** believed that the proposal provides reasonable improvements to processes and notifications.
c. **Ron Clements** expressed mild opposition to the current version of the proposal. VBCOA Admin Committee had additional concerns with the original version of the proposal, and thanked Delegate Milde for being open to their input. **Ron C** noted that after careful

consideration they still have some concerns over how the role of the third-party process would work, whether adequate reviews could be handled by third-party for everything that is required to be reviewed, as well as some concerns with the timeframes.

d. **Michael Dellinger** stated opposition except for third-party reviews. The time frames in the proposal are unrealistic for small one-man shops. This is fine if a project is on a public water sewer system, but they cannot dictate to the applicant that they have to have concurrent Virginia Department of Health or a Virginia Department of Transportation approval.
e. **Rick Hinson** agreed with **Michael D** and added that fixed timelines will not fix the problem. There is a time problem.
f. **Shahriar Amiri** reminded the group that yesterday there was non-consensus for raising fees for state fire marshal services. Those fees are going to provide additional staffing levels to do it faster. This proposal is an unfunded mandate. Code officials have an ethical responsibility not to just rubber stamp for the sake of meeting a timeline.
g. **Mark Graver** declared that he is a small shop and he is the only one doing plan reviews. If he goes on vacation, he could be in violation of this proposal.
h. **Dan Willham** had concerns over the "other structures" deadline because his locality gets really big projects at a time and being required to meet a timeline mandated by law is troubling.
i. **Gregg Fields** disagreed with the Cost Impact statement that the proposal would not increase or decrease cost. Cost will either be increased by increased staff to meet the timelines, or the cost of third-party review. **Gregg F** also highlighted that it is much easier to change things on paper than out in the field. If things get missed in plan review and require tearing out stuff in the field, that will be costly as well.
j. **Delegate Paul M** countered that the costs can be passed down to the applicants, so he was not convinced that it is an affordability issue. The term "within a reasonable time" is not a fair way to approach permits and creating predictability is a fair thing to do to your customers. If the timelines are the issue, he is open to discussing what they should be. Creating predictability creates more affordability.
k. **David Beahm** pointed out that they are not allowed to increase fees arbitrarily to pass costs along. Fees must be approved, and most jurisdictions are not going to increase fees.
l. **Mark G** asserted that in order to determine a correct timeline, the nature of applications coming in waves needs to be factored in. There could be a quiet period and then a very busy period where these timelines can't be met. Small departments would need to have a part-time staff member to help when needed.

DHCD Staff Notes:

1. DHCD convened four Study Groups (SGs) for the 2024 Virginia Code Development Cycle, including the Expediting Permits and Certificates of Occupancy (CO) SG, which originated from House Bill 2682 (2024). The group, which included the proponent of proposal

B109.4-24, met on June 25, 2025, to identify ways to streamline permit and CO reviews and issuance. Its discussions directly informed this proposal. [1]

The original version of the proposal was included on the agenda for the October 3, 2025, GSW meeting, but the proponent requested it be tabled to allow further stakeholder collaboration. The proposal was subsequently revised and included on the third GSW meeting agenda, where it received a Non-Consensus recommendation.

2. This proposal conflicts with proposal B109.2-24, which was also reviewed by stakeholders at the third GSW meeting on January 6, 2026, and received a Non-Consensus recommendation.

[1] See Book 2, Tab 10 for the Expediting Permits and Certificates of Occupancy (CO) Study Group meeting summary.

B109.4(1)-24

VCC: 109.4, 109.4.1, 110.1, 113.7, 113.7.1

Proponents: Anthony Smith, Secure Solar Futures, representing Virginia Distributed Solar Alliance (VA-DSA) (tony@securesolarfutures.com)

2021 Virginia Construction Code

Revise as follows:

109.4 Examination of documents. The building official shall examine or cause to be examined all construction documents or site plans, or both, within a reasonable time after filing. If such documents or plans do not comply with the provisions of this code, the permit applicant shall be notified in writing of the reasons, which shall include any adverse construction document review comments or determinations that additional information or engineering details need to be submitted. The review of construction documents for new one- and two-family dwellings for determining compliance with the technical provisions of this code not relating to the site, location or soil conditions associated with the dwellings shall not be required when identical construction documents for identical dwellings have been previously approved in the same *locality* under the same edition of the code and such construction documents are on file with the *local building department*.

Exception:

For rooftop electrical equipment installations classified as nonstructural electrical equipment and systems installed on existing residential and commercial buildings that applications for a permit have been made by an RDP or a properly licensed Class A contractor shall not require examination. Plans and documents shall be signed and sealed or signed and license number affixed respectively. All plans, documents and construction shall be in accordance with this code.

109.4.1 Expedited construction document review. The building official ~~may~~ shall accept reports from an approved person or agency that the construction documents have been examined and conform to the requirements of the USBC and may establish requirements for the person or agency submitting such reports. In addition, where such reports have been submitted, the building official ~~may~~ shall expedite the issuance of the permit.

110.1 Approval and issuance of permits. The building official shall examine or cause to be examined all applications for permits or amendments to such applications within a reasonable time after filing. If the applications or amendments do not comply with the provisions of this code or all pertinent laws and ordinances, the permit shall not be issued and the permit applicant shall be notified in writing of the reasons for not issuing the permit. If the application complies with the applicable requirements of this code, a permit shall be issued as soon as practicable. The issuance of permits shall not be delayed in an effort to control the pace of *construction* of new detached one- or two-family dwellings.

Exception:

For rooftop electrical equipment installations classified as nonstructural electrical equipment and systems installed on existing residential and commercial buildings, where applications for a permit have been made by an RDP or a properly licensed Class A contractor shall be approved for a permit. Plans and documents shall be signed and sealed or signed and license number affixed respectively affirming that the application complies with the applicable requirements of this code. A permit shall be issued within two weeks from the date of submission of the signed and sealed or signed and license number affixed documents.

113.7 Approved inspection agencies. The building official ~~may~~ shall accept reports of inspections and tests from individuals or inspection agencies approved in accordance with the building official's written policy required by Section 113.7.1 . The individual or inspection agency shall meet the qualifications and reliability requirements established by the written policy. Under circumstances where the building official is unable to make the inspection or test required by Section 113.3 or 113.4 within 2 *working days* of a request or an agreed upon date or if authorized for other circumstances in the building official's written policy, the building official shall accept reports for review. The building official shall approve the report from such approved individuals or agencies unless there is cause to reject it. Failure to approve a report shall be in writing within 2 *working days* of receiving it stating the reason for the rejection. Reports of inspections conducted by approved third-party inspectors or agencies shall be in writing, shall indicate if compliance with the applicable provisions of the USBC have been met and shall be certified by the individual inspector or by the responsible officer when the report is

from an agency. Reports of inspections conducted for the purpose of verifying compliance with the requirements of the USBC for elevators, escalators, and related conveyances shall include the name and certification number of the elevator mechanic performing the tests witnessed by the third-party inspector or agency.

Exception: The licensed mechanical contractor installing the mechanical system shall be permitted to perform duct tests required by Section R403.3.5 of the IECC or Section N1103.3.5 of the IRC. The contractor shall have been trained on the *equipment* used to perform the test.

Note: Photographs, videotapes or other sources of pertinent data or information may be considered as constituting such reports and tests.

113.7.1 Third-party inspectors. Each building official charged with the enforcement of the USBC shall have a written policy establishing the minimum acceptable qualifications for third-party inspectors. The policy shall include the format and time frame required for submission of reports, any reasonable prequalification or preapproval requirements in compliance with the USBC before conducting a third-party inspection and any other reasonable requirements and procedures established by the building official.

Reason Statement: The proposal clarifies that rooftop electrical equipment installations classified as nonstructural electrical equipment and systems installed on existing residential and commercial buildings may be reviewed, certified, and inspected by qualified third-party RDP's. The intent is to reduce administrative burdens on local governments, expedite approvals, and lower costs for property owners while maintaining full compliance with the USBC.

- Virginia faces increasing electricity demand due to rising home and commercial energy consumption and data centers.
- Residential and commercial solar and battery systems can reduce grid strain and improve energy affordability.
- 16% of residential solar projects in Virginia are canceled during the permitting process, primarily due to barriers.
- The cost of residential solar in the U.S. is approximately double that in Europe, largely due to permitting inefficiencies.
- Modernizing local government permitting processes can reduce costs and increase solar adoption.

Common Permitting Issues in Virginia

The proposal addresses significant challenges in the current permitting process for residential and commercial solar installations in Virginia.

- Installers face varying application submission requirements across different jurisdictions, complicating the process.
- Inconsistent code interpretations among local governments lead to confusion and increased costs.
- Communication issues during application reviews create frustration for installers and delays in the process.
- The median wait time for a residential solar permit in Virginia is nine business days, longer for commercial permits, with some jurisdictions taking much longer (as much as one year for commercial permits).
- High and variable permitting fees create additional barriers for solar adoption.

Proposed Solutions for Permitting Challenges

The proposal offers actionable solutions to improve the permitting process for solar installations in Virginia.

- Amend USBC to align application submission requirements across jurisdictions to simplify the process for installers.
- Create exceptions for rooftop electrical equipment to shorten review timelines to expedite the permitting process, aiming for a more efficient system.
- Create exceptions for rooftop electrical equipment for third-party inspection programs to streamline inspections and reduce delays.

Cost Impact: The code change proposal will decrease the cost

The proposed changes will decrease the burdens of government by providing more streamlined review and permitting of rooftop electrical equipment projects that can now be assumed by third party RDPs. It will also reduce taxpayer burden by reducing the costs and time delays for permitting public sector solar projects, such as public schools, that will be more readily able to reduce their energy costs with solar. Following are a few references supporting cost reduction from streamlined permitting, specifically for PV solar.

Streamlining structural engineering compliance of rooftop solar photovoltaic installations using an open-source approach [Solar Energy Journal, 2024]

Cost-Reduction Roadmap for Residential Solar Photovoltaics (PV), 2017–2030 [U.S. Dept. of Energy, National Renewable Energy Lab,

Jan 2018]

A 21st-Century Permitting Regime for Rooftop Solar and Home Batteries in Virginia [Permit Power, Sept 2025]

Streamlining rooftop solar permitting could cut costs by 61%. [PV Magazine, October 27, 2025]

Can cutting rooftop solar costs make up for losing tax credits? [Canary Media, July 23, 2025]

No-Cost Rooftop Solar Stimulus How streamlining residential solar installations can jumpstart a green economic recovery [San Francisco Planning and Urban Research Association (SPUR), May 2021]

- **SPUR_a_no_cost_rooftop_solar_stimulus.pdf**
  https://va.cdpaccess.com/proposal/1498/2167/documentation/11687/attachments/download/1006/
- **NREL SolarAPP+ Performance Review (2023 Data).pdf**
  https://va.cdpaccess.com/proposal/1498/2167/documentation/11687/attachments/download/1005/
- **NREL Cost reducation roadmap for residential solar rooftop.pdf**
  https://va.cdpaccess.com/proposal/1498/2167/documentation/11687/attachments/download/1004/
- **Cheap-as-our-peers-1.pdf.pdf**
  https://va.cdpaccess.com/proposal/1498/2167/documentation/11687/attachments/download/1003/
- **Can cutting rooftop solar costs make up for losing tax… _ Canary Media.pdf**
  https://va.cdpaccess.com/proposal/1498/2167/documentation/11687/attachments/download/1002/
- **A-21st-Century-Permitting-Regime-for-Rooftop-Solar-and-Home-Batteries-in-Virginia-6.pdf.pdf**
  https://va.cdpaccess.com/proposal/1498/2167/documentation/11687/attachments/download/1001/

Attached Files

- **SPUR_a_no_cost_rooftop_solar_stimulus.pdf**
  https://va.cdpaccess.com/proposal/1498/2167/files/download/1012/
- **NREL SolarAPP+ Performance Review (2023 Data).pdf**
  https://va.cdpaccess.com/proposal/1498/2167/files/download/1011/
- **NREL Cost reducation roadmap for residential solar rooftop.pdf**
  https://va.cdpaccess.com/proposal/1498/2167/files/download/1010/
- **Cheap-as-our-peers-1.pdf.pdf**
  https://va.cdpaccess.com/proposal/1498/2167/files/download/1009/
- **Can cutting rooftop solar costs make up for losing tax… _ Canary Media.pdf**
  https://va.cdpaccess.com/proposal/1498/2167/files/download/1008/
- **A-21st-Century-Permitting-Regime-for-Rooftop-Solar-and-Home-Batteries-in-Virginia-6.pdf.pdf**
  https://va.cdpaccess.com/proposal/1498/2167/files/download/1007/

SPUR

POLICY BRIEF
MAY 2021 UPDATE

A No-Cost Rooftop Solar Stimulus

How streamlining residential solar installations can jumpstart a green economic recovery

Acknowledgements

Authors: Susannah Parsons and Nick Josefowitz

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Introduction

As California looks to exit the pandemic, the need for a green recovery through the expansion of rooftop solar energy generation and energy storage has never been clearer. This expansion would help address climate change by meeting the state's renewable energy targets, protect communities from wildfires and public safety power shutoffs, and grow local jobs and small businesses in every California community. This brief lays out a set of quick, no-cost actions that state and local governments can take to begin this expansion and updates SPUR's 2020 policy brief with new data and a renewed urgency.

Cities and counties have an opportunity to tackle the long-standing barrier to solar and storage adoption: the "soft costs" associated with permitting and inspection. These processes are intended to protect residents and promote safety, but they can complicate and delay solar installations, particularly for routine, small-scale residential solar and storage systems. In effect, local and state governments should treat installing rooftop solar panels more like getting an appliance such as a new HVAC system or washing machine and less like a construction process, such as a seismic retrofit of a home. By bringing down these "soft costs" while still guaranteeing safety, California and the Bay Area can address economic recovery, resilience and climate change goals at once.

The Golden Solar State

California has established a world-leading energy policy and regulatory approach to reducing climate emissions and transitioning to a fossil-free economy. In particular, Assembly Bill 32 (2006) established the goal of reducing statewide greenhouse gas emissions from all sectors of the economy to 1990 levels by 2020. Senate Bill 32 (2016) expands that requirement to 40% below 1990 levels by 2030. California's renewable portfolio standard, first established in 2002, requires the state to deliver 50% renewable electricity by 2030 and now, Senate Bill 100 (2018) has expanded the standard to 100% renewable by 2045. But despite the state's past success, emissions reductions must accelerate in order to meet the targets by the end of this decade. The California Air Resources Board, California Public Utilities Commission and California Energy Commission estimate the state will need to triple the rate of solar energy generation, including rooftop installations, in order to achieve 100% renewable energy.[1]

Residential solar and storage is an important part of the state's clean energy transition and low-carbon future. California's sunny weather brings abundant solar energy to most parts of the state year-round. For customers, installing rooftop solar panels reduces their electricity bills, and for utility companies, decreases the need for costly grid upgrades, like new transformer stations, to meet increased energy demand. In 2018, the state cancelled or revised $2.6 billion worth of grid transmission projects, savings attributed primarily to increased rooftop solar installations.[2]

Rooftop solar brings critical resilience benefits as well. In 2020, the three largest energy utilities conducted 21 public safety power shutoffs due to record wildfires, slightly less than all such shutoffs in the prior six years

1 California Energy Commission, SB 100 Joint Agency Report, 2021, https://www.energy.ca.gov/sb100

2 California Independent System Operator, "2017-2018 Transmission Plan," https://static1.squarespace.com/static/54c1a3f9e4b04884b35cfef6/t/5ab933322b6a28bbf5c5f130/1522086756653/CAISO-2017-2018_Transmission_Plan.pdf

combined.[3] One of those shutoffs, from Sept 7-10, shut down power for 172,000 customers across 22 counties.[4] These interventions will undoubtedly continue as the climate warms and utilities look to better manage risk: A recent court ruling could result in triple the number of power shutoffs in counties across PG&E's territory in 2021. Rooftop solar, particularly when paired with a battery, can keep the lights on as well as medical devices running through these shutoff emergencies.

Prior to the COVID-19 pandemic, California was well-positioned to accelerate adoption of rooftop solar. The 2019 state building code update requires solar systems on new home construction, a regulatory change that builds upon other policies like net-metering, where customers are reimbursed for the electricity their panels generate and send back to the grid, and other incentives for customers to install rooftop solar and storage. National residential solar installations increased 11% in 2020 over the previous year, continuing a steady upward trend in demand since 2016.[5] The solar industry was also widely considered a driver of green economic growth, adding more than 150,000 jobs across the United States in the last decade and growing at five times the rate of the overall economy.[6] In 2018, the Federal Bureau of Labor Statistics predicted that solar installers in particular would be the fastest growing job over the coming decade.[7] California already employed more than 74,000 solar workers, the majority of whom were installers. These are high potential jobs: median hourly wages for solar industry jobs overall are about 28% higher than the national median wage and are more likely to come with health care and retirement benefits than jobs across the rest of the private sector.[8]

Delivering Rooftop Solar Today

Installing rooftop solar is about twice as expensive in the United States as it is in a country like Germany, despite similar wages and equipment costs.[9] What's behind these differences? As the cost of technology have declined over time, the "soft costs" account for a significant share of the total price of a solar system.[10] For a customer, the soft costs specifically associated with solar installation, including costs for permitting and inspectioncan amount to as much as $1 per watt of the installation, or $5,000 for a typical rooftop system in California.[11] The biggest culprit behind high soft costs is usually time: despite the state's well-established rooftop solar industry, and some legislative reforms, described below, average wait times between when a permit has been submitted and completion of a successful building inspection have remained consistent at 45 to 50 days over the last decade.[12]

3 See https://www.cpuc.ca.gov/psps/ and https://www.cpuc.ca.gov/general.aspx?id=6442467662

4 Pacific Gas and Electric Company, 2020, "compliance report letter on proactive de-energization," https://www.pge.com/pge_global/common/pdfs/safety/emergency-preparedness/natural-disaster/wildfires/PSPS-Report-Letter-09.07.20.pdf

5 Solar Energy Industry Association, 2021, "2020 Market Insight Report" https://www.seia.org/research-resources/solar-market-insight-report-2020-year-review

6 2019 Solar Jobs Census, The Solar Foundation, https://www.thesolarfoundation.org/national/

7 2019-2029 Employment Projections, Bureau of Labor Statistics, https://www.bls.gov/news.release/ecopro.nr0.htm

8 Clean Jobs, Better Jobs, E2/Acore/CELI; https://e2.org/wp-content/uploads/2020/10/Clean-Jobs-Better-Jobs.-October-2020.-E2-ACORE-CELI.pdf

9 Andrew Birch, 2018, "How to Halve the Cost of Residential Solar in the US," https://www.greentechmedia.com/articles/read/how-to-halve-the-cost-of-residential-solar-in-the-us

10 SEIA/Wood Mackenzie Power & Renewables, 2021, "Solar Market Insight Report: 2020 Year in Review," 2020, https://www.seia.org/research-resources/solar-market-insight-report-2020-year-review

11 Soft costs vary based on factors like local sales tax, jurisdictions' permitting systems and installer cost structures. The National Renewable Energy Laboratory models cost benchmarks on a quarterly basis. The upper limit reflects this benchmarking and includes the additional indirect soft costs like customer acquisition. See https://www.nrel.gov/docs/fy21osti/77324.pdf and https://www.seia.org/initiatives/solar-automated-permit-processing-solarapp. Energy Sage provides average installation pricing based on location and system size.

12 O'Shaughnessy, Barbose and Wiser, 2020, "Patience is a virtue: A data-driven analysis of rooftop solar PV permitting timelines in the United States," https://emp.lbl.gov/

Behind High Soft Costs: Permitting and Inspection Challenges

Each rooftop solar system requires a building permit, similar to what's required to build a new foundation for a home, as well as physical inspection before it can be connected to the grid and begin operating. The local permitting authority (usually a building department) takes a substantial fee (up to $450) to review applications to ensure the system meets building code requirements. The process delay behind high soft costs for solar and storage systems is driven in large part by the patchwork of unstandardized and uncoordinated requirements and processes across California's 500+ cities and counties. The base building code is set by the State of California, but individual cities and counties interpret the same building code sections differently, and some impose their own additional unique code requirements. For example, one jurisdiction reviews solar plus storage systems on single-family homes according to the fire code, while the rest of the state uses the residential code. Another jurisdiction requires a minimum of three or four batteries installed per solar system — far more storage capacity than a typical home needs — based on interpretation that the battery in a solar plus storage system must be able to supply energy loads for every device and appliance in the home operating at the same time. Even within jurisdictions, different building code officials have developed different and unwritten interpretations of building codes, leading to uncertainty among installers and significant proportions of applications need to undergo corrections. Permit application submission itself varies greatly, where some building departments manage online databases but others require in-person and paper applications. Some jurisdictions may be able to provide an online portal and a clear and seamless experience while others struggle to manage outdated systems.

After a rooftop solar system is permitted and installed, it must be physically inspected to ensure code compliance, such as proper wiring methods, structural integrity of the building and fire safety measures. Some cities conduct multiple inspections over the course of construction and, in some cases, additional agencies like the fire district will conduct separate checks. As with the permitting process, there is significant variability in department expertise or interpretation of building codes between jurisdictions. The lack of a standardized and shared set of requirements for inspection causes confusion between inspectors and installers, and results in avoidable mistakes — on top of the logistical challenge of scheduling waiting for inspections.

Ultimately, the variability in code interpretation, permit submission, inspection delays and other factors has significant impacts for installers, customers and ultimately the state's ability to achieve its climate targets. The Solar Energy Industry Association reports that a one-week delay as a result of permitting, inspection and interconnection processes results in a customer cancellation rate between 5-10%. This drives down customer satisfaction, and increases the cost for installers to secure each additional new customer. It also increases the cost of managing crews and inventory across a regional market where requirements and installation timelines vary. The accumulated cost over the next 10 years is significant: assuming rooftop solar installations triple in California, we risk imposing up to $7.5 billion in unnecessary soft costs in our effort to meet the state's clean energy targets.[13]

With more than 1 million rooftop solar installations in California and most sharing similar characteristics, the state can evolve permitting and inspection to reflect accumulated knowledge and best practices, and to allow for the scale of adoption needed to meet the state's clean energy targets.

publications/patience-virtue-data-driven-analysis

13 Based on the estimate that permitting and inspection-related soft costs can total up to $1 dollar per watt of installation. California installed roughly 1,000 MW of residential rooftop solar in 2019. See: https://www.seia.org/state-solar-policy/california-solar

Permitting for a Rooftop Solar Stimulus

Customers, advocates and research organizations — including SPUR — have long called for changes to the permitting and inspection process for rooftop solar systems.[14] And there has been some incremental success.

Past Permitting Reforms

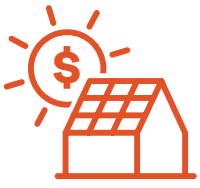
SB 1222 (Leno, 2012) and AB1414 (Friedman, 2017) capped permit fees based on the size of the system. AB 2188 (Muratsuchi, 2014) required local governments to create a streamlined permitting process for small (under 10 kilowatt) rooftop solar systems according to the state's the Solar Permitting Guidebook, which establishes best practices in solar permitting, such as a model streamlining ordinance and standardized inspection checklists. As a result, local jurisdictions must allow applications to be filed online for rooftop solar systems, limit permit review timeframes and consolidate inspection visits. However, many jurisdictions still do not fully comply more than seven years later, most often because permit review time frames still vary significantly from project to project.[15] Other requirements are partially implemented; for example a jurisdiction will allow for a permit application to be submitted online, but applicants must show up at the Building Department and stand in line to receive the permit itself. While some jurisdictions may make a good faith effort to comply, AB 2188 included no mechanism to enforce compliance. At the same time, growing demand for solar means that these permit applications dominate the permitting queue in some jurisdictions, while others have already begun to anticipate increased workload as California transitions its building stock to all-electric in the coming years.[16]

Permitting for a Rooftop Solar Decade

What Could Solar Permitting Improvements Deliver for California?



3 TIMES
the solar installations to meet California's clean energy targets



$7.5 BILLION
in soft cost savings



$111 MILLION
in increased annual permit fee revenue for cities and counties



780,000 JOBS
in the solar industry

14 SPUR calls for streamlined permitting for solar systems in Fossil Free Bay Area (2016).

15 Taylor et al. found that as of 2019, 31% of jurisdictions did not comply with AB 2188, indicated by having adopted a local streamlining ordinance with the four parameters outlined in the original law. Anecdotal reports, however, suggest that compliance may be even more uneven within jurisdictions between projects, in part because the timeline requirements are not consistently met. See: Taylor et al., "Explaining jurisdictional compliance with California's top-down streamlined solar permitting law (AB 2188)," 2019, https://eta-publications.lbl.gov/sites/default/files/ab2188-streamlined_solar_permitting_reform_10-7_-_margaret_taylor.pdf

16 TRC Consulting, "Best Practices Guide for Streamlining Electrification Permitting," May 2021, Publication forthcoming.

There's a clear opportunity to evolve the permitting and inspection process in California that allows for more efficient use of staff time, reduces confusion and still ensure safety. "Instant permitting" shows particular promise: Cities including Los Angeles, San José, and Santa Barbara have all implemented an online portal that returns instant permits for rooftop solar systems with success (see sidebar). As part of its COVID-19 response, San Luis Obispo recently moved to both fully online and instant residential solar permitting. The city has reduced some projects' total installation time (from sale to permit approval to successful building inspection) to just 12 hours.

Reducing a months-long process down to an hour or less would accelerate the number of solar systems installed, consistent with what's needed to hit the state's clean energy goals. In fact, the National Renewable Energy Laboratory has found that jurisdictions with online and automated permitting (where an applicant can receive a permit immediately after submitting plans, answering a series of questions and paying their fee) approve an average of 14 times the number of applications as jurisdictions with a traditional over-the-counter process.[17]

Increasing the rate at which Californians install solar would bring a number of associated benefits. For a jurisdiction that typically approves 1,800 rooftop solar permits a year with a permit fee of $300, tripling the number of approvals could increase their fee revenue to $1.5 million or more. Statewide, tripling the number of residential solar installations along with the permit fees, could bring an additional $111 million a year to local governments in California.[18]

For customers, the benefits extend beyond the $3 billion in avoided soft cost described above. Recent research estimates that electrifying homes with rooftop solar could save the average American household as much at $2,500 a year.[19] Ratepayers could save billions in avoided grid upgrades. And the state could leverage a major opportunity for job growth: past research suggests that tripling rooftop solar installations could create 780,000 jobs over the next ten years.[20] The vast majority of solar companies are local, small businesses with under 100 employees, and these jobs pay well with few barriers to entry.[21]

17 Based on the National Renewable Energy Laboratory Solar TRACE tool, 2021. Dataset forthcoming: https://solarapp.nrel.gov/solarTRACE

18 Estimates based CA historical residential solar installations and median permit fee ($350 per project). See National Renewable Energy Laboratory Solar TRACE tool, 2021. Dataset forthcoming: https://solarapp.nrel.gov/solarTRACE

19 Rewiring America, "No Place Like Home: Fighting climate change and saving money by electrifying American households," 2020, https://static1.squarespace.com/static/5e540e7fb9d1816038da0314/t/5f9290062226271c5b66b7d0/1603440672253/Households+Technical_White_Paper.pdf

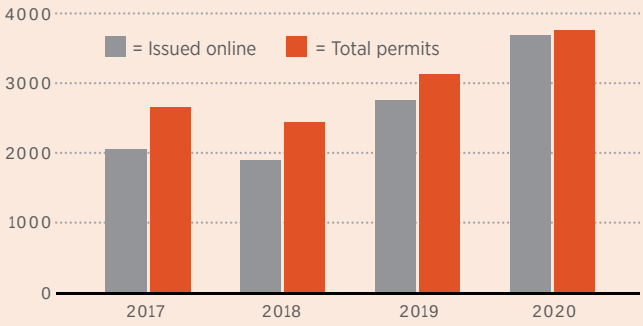
20 Estimate of 26 jobs per every 1 MW installed solar, based on research from NREL's JEDI model. See https://rmi.org/how-covid-19-is-pushing-cities-to-change-solar-permitting-for-the-better/

21 Brookings Institution, "How clean energy jobs and power an equitable COVID-19 recovery," 2020, https://www.brookings.edu/blog/the-avenue/2020/09/10/how-clean-energy-jobs-can-power-an-equitable-covid-19-recovery/. See also: https://www.thesolarfoundation.org/national/

Going instant and online in San José

In 2015, San José implemented a system that allowed for online permit submission for solar systems, but also provided instant approvals. Applicants receive a $40 discount for submitting online, and are able to schedule an inspection through the portal as well. As a result, San José saw a more than 600% increase in residential rooftop solar permits in the following year (In contrast, the growth of residential solar systems across California was 3.3% that same year)[22]. While the city has maintained its over-the-counter option, recent data show that in addition to solar permits increasing, the percent of applicants choosing to process online has also increased. In 2020, 98% of solar permit issuances occurred through the city's online and instant portal. San José added battery storage to the instant permit system in August of last year.

Solar Permits Issued 2017–2020



San Jose permit issuances continue to increase after implementing an online, automated permitting process, and use of the that system has grown over time. Today, the vast majority of solar permits in the city are issues through the automated system. Source: San Jose Building Department permit issuances. Available upon request.

Policies to Support Streamlined Rooftop Solar Permitting and Inspection

Local governments across the California should pursue several significant steps to dramatically reduce the cost of small residential solar installations — and increase their uptake and associated economic benefits. The state should also require all local governments to adopt these best practices within the next few years, to speed expansion.

1. **Improve upon AB 2188 and drive local compliance.** Research shows that fully online permit processes, as opposed to a hybrid of in-person and online options, are what make a meaningful impact on application timelines. The state could improve on AB 2188 by requiring that jurisdictions accept online permit applications (current law only requires that they provide for online submission and electronic signatures). Implementation of prior permit streamlining law has been uneven across jurisdictions. The state should provide incentives in the form of grants and technical assistance to drive more consistent compliance. The

22 Based on interconnection data for the state's Distributed Generation Statistics for California's investor-owned utility territory (Pacific Gas & Electric, Southern California Edison and San Diego Gas & Electric. https://www.californiadgstats.ca.gov/charts/nem

state should also hold jurisdictions accountable for non-compliance, either through legal action or making new grant funding contingent on AB 2188 compliance.

2. **Standardize local building codes and inspections requirements for rooftop solar across the Bay Area.** A household appliance like a washing machine would be significantly more expensive if manufacturers had to produce enough models to comply with thousands of different cities' code requirements — the same argument can be made for rooftop solar and storage systems. Local jurisdictions should only modify state building codes with regard to solar and storage to address specific local risks (like snow loads, wind loads and temperature), and should do so in a standardized way. A standard set of requirements for rooftop solar and storage would go a long way toward reducing delay and uncertainty in the inspection process.

3. **Provide automated and instant approval for online applications.** By creating online applications that ask standardized questions and filter for compliant answers, software can easily provide automated and instant approval for solar permits. This software would virtually eliminate the permitting cost born by local jurisdictions and cut permit application processing time to zero for most small residential systems. A number of California jurisdictions have created their own instant systems, but at significant expense. However, the National Renewable Energy Laboratory (a division of the federal Department of Energy) has created an online portal, SolarAPP, that is open-source and free for jurisdictions to adopt. This portal is a significant opportunity to reduce permit timelines, relieving building department workloads and standardizing processes across the state (see sidebar).

4. **Reduce or eliminate permit fees for rooftop solar systems.** Permitting fees are used to subsidize the administrative cost of processing new solar projects. Ultimately, if jurisdictions improve their permitting and inspection processes with automated and instant online permitting, these fees could be reduced or eliminated for the vast majority of rooftop solar installations — which would increase access to solar panels for more would-be customers.

5. **Explore offering virtual building inspections.** Virtual inspections would allow building inspectors to inspect many more worksites a day and better manage workloads, while reducing the delay associated with scheduling a building inspection visit and the amount of time that contractors must wait on site for the building inspector to arrive. Los Angeles has provided virtual building inspections since 2019. The pandemic prompted a number of cities to allow their building inspectors to perform virtual home visits and safety organizations like International Code Council, National Fire Protection Association and International Association of Electrical Inspectors have offered guidance. Cities and counties should consult best practices, engage with stakeholders including those organizations who represent building inspection officials, and explore this option for residential systems.

AB 2188 has demonstrated that a few jurisdictions adopting best practices is not enough; cities and counties across California should implement these ideas in order to drive more widespread adoption and meet the state's clean energy targets. What's more, widespread implementation reduces barriers to solar for more people and more communities, while allowing contractors to better plan for a customer market that spans political boundaries.

SolarAPP: The new national standard

Until recently, jurisdictions like San José had to build custom software solutions to address permitting challenges for rooftop solar. Over the past year, however, the National Renewable Energy Laboratory has partnered with solar companies and code enforcement officials to create the Solar Automated Permit Processing platform (SolarAPP), an online and automatic solar permitting software that local jurisdictions across the United States can use for free. SolarAPP was developed with national building code and safety agencies like the International Code Council, Underwriters Laboratories and the National Fire Safety Association. The platform is built according to the national electrical code, though it also allows for local customization options around snow, fire and earthquake safety requirements.

Like with a credit card application, SolarAPP asks a set of standardized questions and only accepts applications with compliant answers. SolarAPP then provides an instant assessment of the system's compliance with state building codes and instantaneously approves or identifies the noncompliant answers. Importantly for local governments, it can be used on its own or integrated with online permitting management software that some jurisdictions already use, and allows local jurisdictions to collect permit fees within it.

Finally, SolarAPP also produces a standardized building inspection checklist that can integrate with any inspection process, including virtual inspections. The platform is in use in jurisdictions around the country, and has issued more than 100 automatic solar permits since its rollout in January 2021. About 50 jurisdictions in California are in various stages of exploring or implementing SolarAPP, including the city of Pleasant Hill. Going forward, NREL will expand the software to include compliance checks for batteries and electric vehicle charging.

Beyond Rooftop Solar: Streamlining Electrical Vehicle Charging and Building Decarbonization

In some ways, rooftop solar is just the beginning of a major transition for California's built environment. Today, buildings account for 25% of the state's carbon emissions; in the coming decade, more of California's building stock will transition to low- or no-carbon, and hundreds of thousands of electric vehicle charging stations will need to be installed. In fact, Governor Newsom signed an executive order[23] setting a target that 100% of in-state sales of new passenger vehicles will be zero-emission by 2035. Getting to 100% EV sales hinges on rapidly building out charging infrastructure, an effort that will accelerate job growth and economic recovery. Yet the delays and costs for permitting electric vehicle charging stations are even more significant than those for rooftop solar and storage.[24] This issue also extends to the replacement of gas-fired appliances with clean electrical ones (like electric heat pumps), as the replacement often needs to be done within a day or two when an appliance breaks, leaving no time for lengthy permitting and building inspections. By successfully streamlining our solar and storage permitting, and working through challenges that arise, cities will provide the roadmap for what we need to do for electric vehicle charging, building decarbonization permitting and beyond.

23 Rocky Mountain Institute, 2019, "Reducing EV Charging Infrastructure Costs," https://rmi.org/insight/reducing-ev-charging-infrastructure-costs/

24 Rocky Mountain Institute, 2019, "Reducing EV Charging Infrastructure Costs," https://rmi.org/insight/reducing-ev-charging-infrastructure-costs/

Conclusion

As cities and counties emerge from the COVID-19 pandemic, they face both the newfound need for job and small-business creation as well as the continued threats of wildfires and climate change. Expanding rooftop solar and storage can spur local economic development, increase energy resilience and move the state closer to its emissions targets. But success will require a permitting process that is simple and automatic for homeowners, installers and regulators.



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SolarAPP+ Performance Review (2023 Data)

Jeff Cook,[1] Sertac Akar,[1] Danny Chang,[1]
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1 National Renewable Energy Laboratory
2 Clean Kilowatts LLC

Technical Report
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Executive Summary

The Solar Automated Permit Processing Plus (SolarAPP+) platform is an online portal designed to facilitate and expedite residential rooftop solar photovoltaic (PV) and battery storage permitting processes. SolarAPP+ allows PV contractors to upload system specifications, have that information automatically reviewed for code compliance, and receive instant approval for code-compliant systems, reducing the authority having jurisdiction (AHJ) staff time needed for review. SolarAPP+ also provides inspection checklists to verify installation practices and adherence to approved designs. SolarAPP+ is available to AHJs at no cost.

Consistent with previous performance reviews, in this report we summarize SolarAPP+ adoption trends to date and compare various metrics for PV systems permitted through SolarAPP+ to those for systems permitted through traditional AHJ permitting processes.

As of the end of 2023, 752 AHJs had expressed interest in the platform, with 167 AHJs either fully adopting (97) or piloting (70) the platform. In 2023, 668 installers submitted 18,906 permits through the SolarAPP+ platform, including 4,834 permits for PV+storage systems. SolarAPP+ permits accounted for around 43% of all permits issued in all participating AHJs (Figure ES-1), and more than 80% of all permits in several participating AHJs.

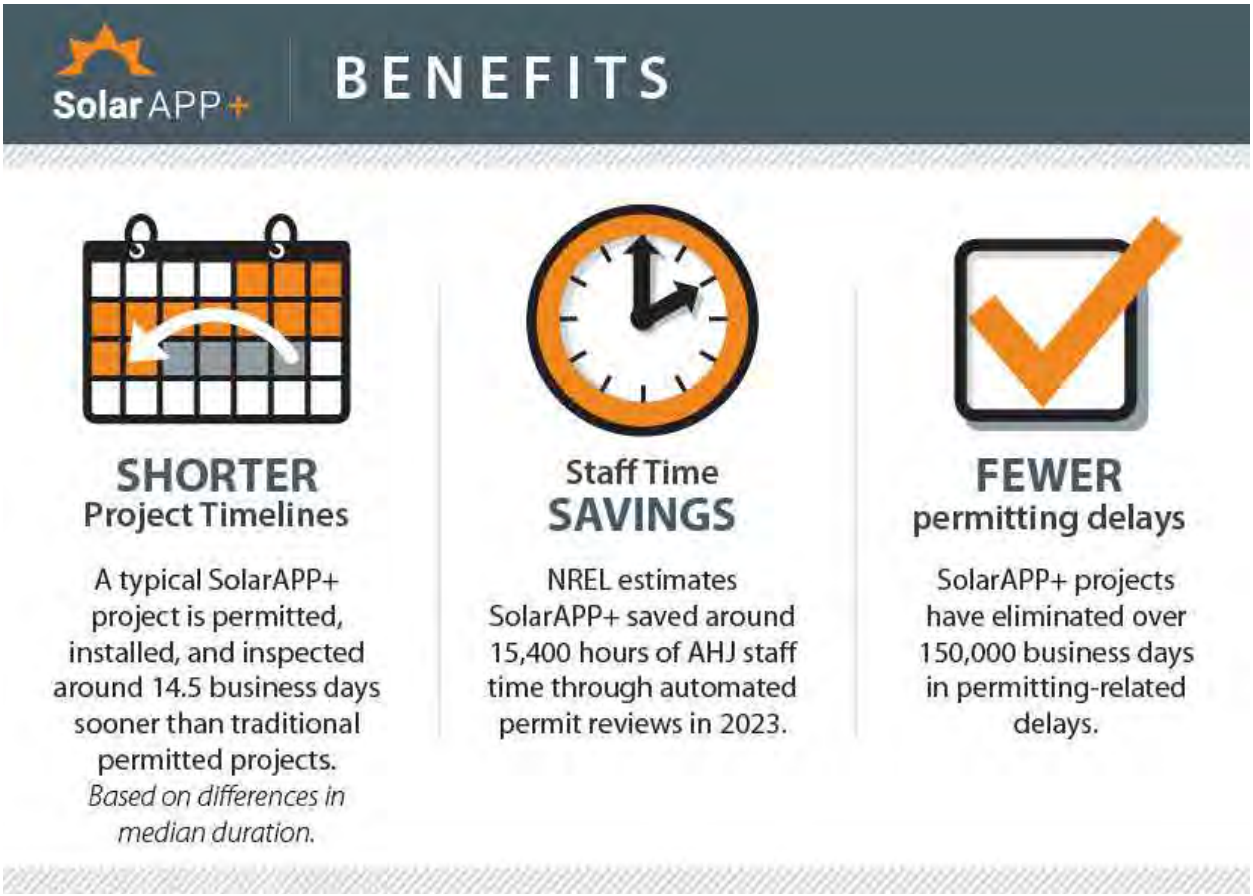


Figure ES-1. Summary of performance review results

Consistent with previous SolarAPP+ performance reviews, we find that permitting timelines are significantly shorter for SolarAPP+ projects as compared to traditionally permitted projects. In 2023, we estimate that:

- A typical SolarAPP+ project is permitted and inspected 14.5 business days sooner than traditional projects (based on median timelines).
- Automatic SolarAPP+ permitting saved around 15,400 hours of AHJ staff time and collectively accelerated PV permitting by around 150,000 business days in 2023.
- SolarAPP+ reduced PV installation costs by around 2%–13%, increased rooftop PV deployment by around 2%–17%, abated around 0.5M-2.0M tCO_2 emissions, and saved around $945,000 in household electricity costs in SolarAPP+ AHJs.

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1 Introduction

The Solar Automated Permit Processing Plus (SolarAPP+) platform is an online portal designed to facilitate and expedite permitting of residential rooftop solar photovoltaic (PV) and battery storage systems. SolarAPP+ was developed by the National Renewable Energy Laboratory (NREL) in collaboration with local governments, code development organizations, and industry stakeholders. SolarAPP+ is available to local permitting authorities at no cost.

This report is part of an ongoing series of reviews of SolarAPP+ performance. Consistent with previous performance reviews, we summarize SolarAPP+ adoption trends to date and compare various metrics for PV systems permitted through SolarAPP+ to those for systems permitted through traditional authority having jurisdiction (AHJ) permitting processes. In this introduction, we briefly explain the impetus for SolarAPP+ development, the functions of the platform, and the results of previous performance reviews.

1.1 The Need for Standardized PV Permitting

Most rooftop PV systems are subject to local permitting requirements implemented by local AHJs. Figure 1 depicts a typical permitting process and how it relates to the interconnection processes implemented by utilities. Rapid and accelerating rooftop PV deployment has strained the capacity of AHJs to efficiently navigate these processes (Cook et al. 2021). Conversely, although states typically set minimum requirements, individual AHJs often implement unique permitting requirements (Stanfield et al. 2012). Local permitting variability has presented a challenge to the expanding rooftop PV market by increasing compliance costs (Dong and Wiser 2013; Burkhardt et al. 2015; Cook et al. 2021) and permitting timelines (O'Shaughnessy et al. 2022). A growing number of AHJs and utilities have responded by reforming and standardizing permitting processes to reduce delays (Stanfield et al. 2012; Fekete et al. 2022). However, PV permitting reforms have, to date, occurred in a piecemeal fashion, and many AHJs lack the resources to implement reforms (Parsons and Josefowitz 2020).

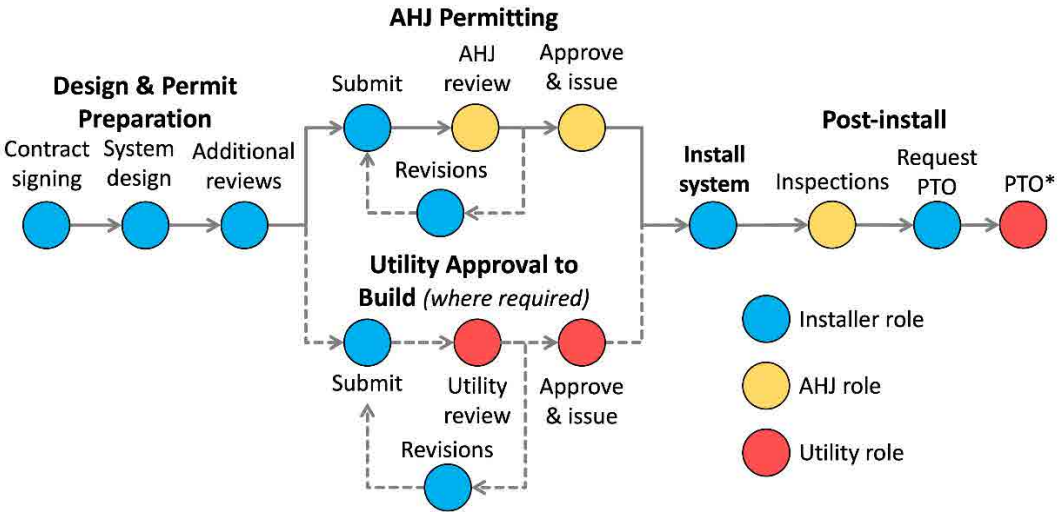


Figure 1. The rooftop PV permitting process

1.2 The SolarAPP+ Platform

SolarAPP+ was developed by NREL in response to the evolving challenges in rooftop PV permitting. NREL developed the platform in collaboration with industry and the building safety community, with funding from the U.S. Department of Energy. SolarAPP+ streamlines AHJ permitting for residential rooftop PV systems that meet certain eligibility requirements,[1] automating the review of eligible systems through the steps illustrated in Figure 2. SolarAPP+ allows PV contractors to upload system specifications, have that information automatically reviewed for code compliance, and obtain instant approval for code-compliant systems. Based on the application inputs, SolarAPP+ also generates checklists and electrical schematics for inspectors to confirm that installed systems match preapproved designs. The SolarAPP+ project formally began in September 2019 with development and testing of the software for alignment with national model codes. NREL piloted the software with five communities in 2021 (Williams et al. 2022). SolarAPP+ was then officially launched in July 2021.

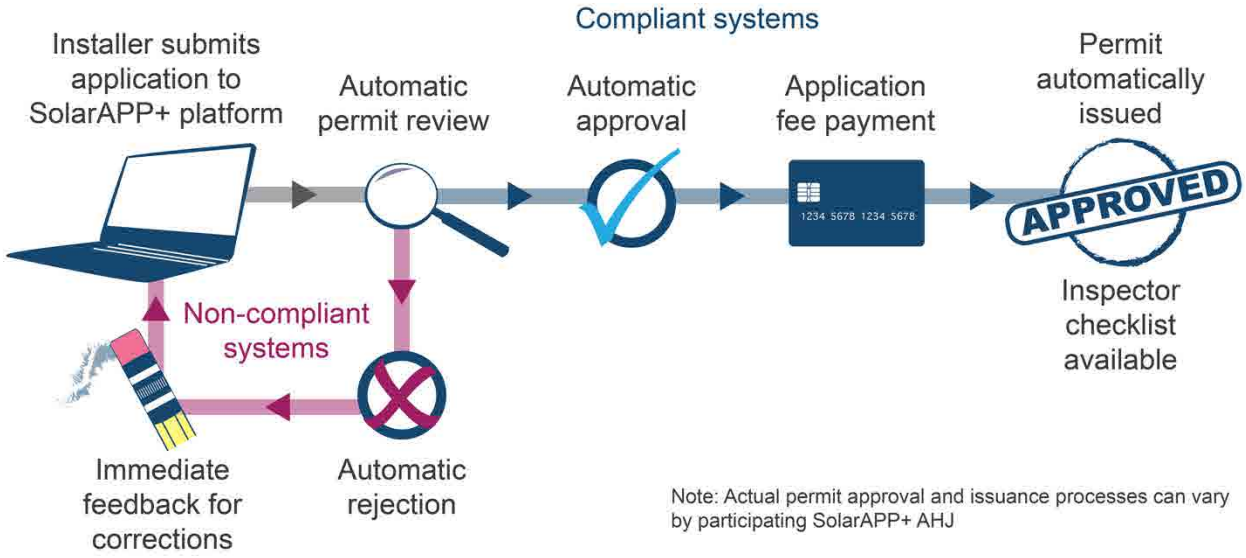


Figure 2. Example SolarAPP+ permit application and approval process

Note: In most AHJs, the fee payment and permit issuance occurs via the AHJ's existing permitting system.

1.3 Past SolarAPP+ Performance Reviews

NREL has published three reviews of SolarAPP+ platform performance to date. Williams et al. (2022) analyzed the performance of five SolarAPP+ pilots, Cook et al. (2022) evaluated platform performance in 10 AHJs that had piloted or implemented SolarAPP+ by the end of 2021, and Cook et al. (2023) evaluated performance in 31 AHJs that had piloted or implemented SolarAPP+ by the end of 2022. The three reviews reach similar conclusions:

- SolarAPP+ saves AHJ staff time otherwise spent on permit and revision reviews.

[1] For a complete list of the eligibility requirements, see https://help.solar-app.org/article/43-what-types-of-systems-are-not-eligible-for-solarapp-review.

- SolarAPP+ instantly issues permits for code-compliant systems, effectively reducing permit review times to zero. By contrast, typical review times through traditional permitting processes are a week or more.

- SolarAPP+ projects had similar inspection durations and passed inspections at similar rates as other projects.

- SolarAPP+ projects complete the full permitting timeline (permit submission to passed inspection) faster than projects using traditional permitting processes.

This report builds on and largely corroborates the results from these previous performance reviews with updated results for projects permitted in 2023.

2 SolarAPP+ Implementation

As of the end of 2023, NREL had contacted over 1,700 AHJs as potential users of the SolarAPP+ platform. Of these, 752 were interested in implementing SolarAPP+.[2] Interested AHJs are geographically distributed throughout the United States and are at various stages in the implementation process (Figure 3). Of the 752 interested AHJs, 127 AHJs were in a technical demonstration stage, 83 AHJs were evaluating and testing SolarAPP+, 66 AHJs were in pilot onboarding, 70 AHJs were in a pilot stage, and 97 AHJs had publicly launched the platform. Interested AHJs have a range of demographic features; 192 of the interested AHJs meet one typical criterion for identifying a community as disadvantaged (median income less than 80% of state median income).

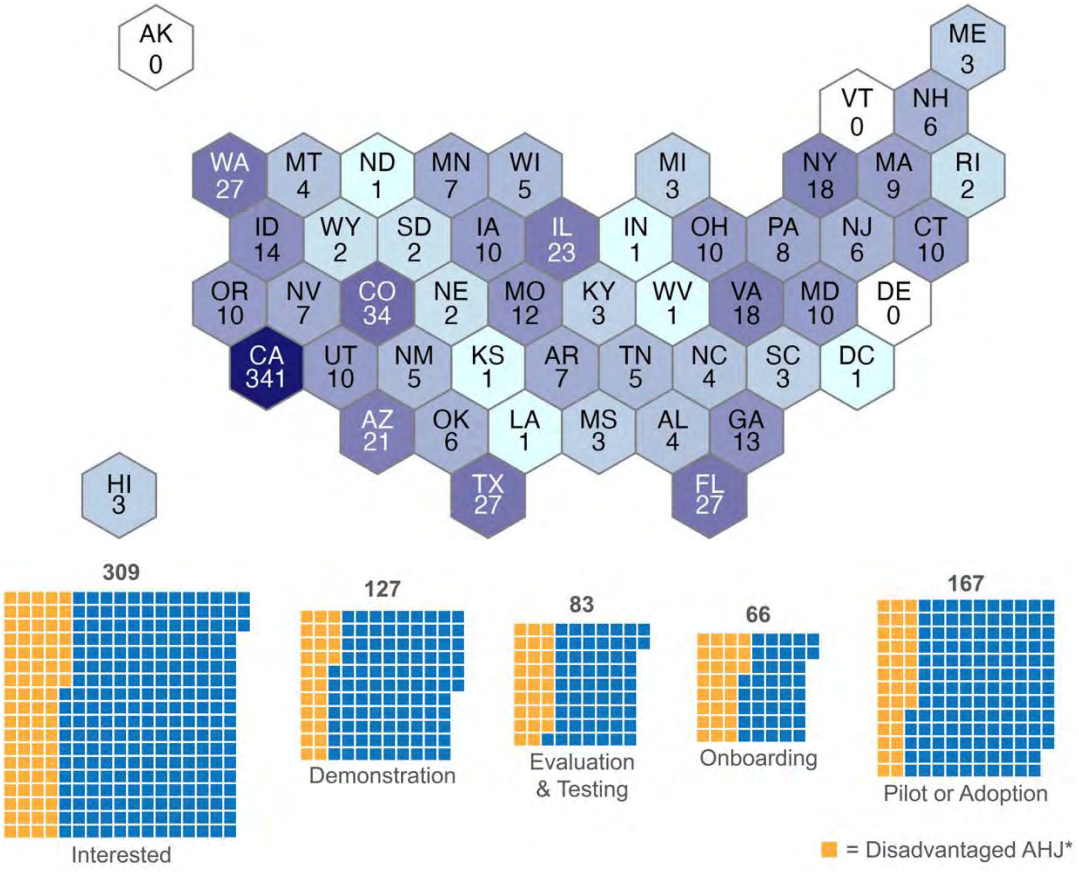


Figure 3. Number of AHJs that have expressed interest in SolarAPP+, by state (top pane) and by adoption stage (bottom pane)

* Refers to AHJs with median income less than 80% of state median income

Figure 4 depicts the platform implementation timelines for the 97 AHJs that had adopted SolarAPP+ by the end of 2023, ordered by the timing of the first interaction. These AHJs are the focus of this study. The median duration from first interaction to pilot was 505 days (or 553 days

[2] An expression of interest occurs when an AHJ follows up on an initial contact, and it includes AHJs at any level of implementation: demonstration, evaluation, testing, pilot, or adoption.

on average), and the median duration from pilot to public adoption was 69 days (or 114 days on average). About 48% of AHJs moved from pilot to adoption in fewer than 3 months, and 84% of AHJs completed the process in fewer than 6 months (Figure 5). Over 70 AHJs adopted SolarAPP+ in the final months of 2023 (Figure 6), due largely to the implementation of a new policy in California requiring AHJs to adopt automatic permitting processes.



Figure 4. AHJ SolarAPP+ implementation timelines

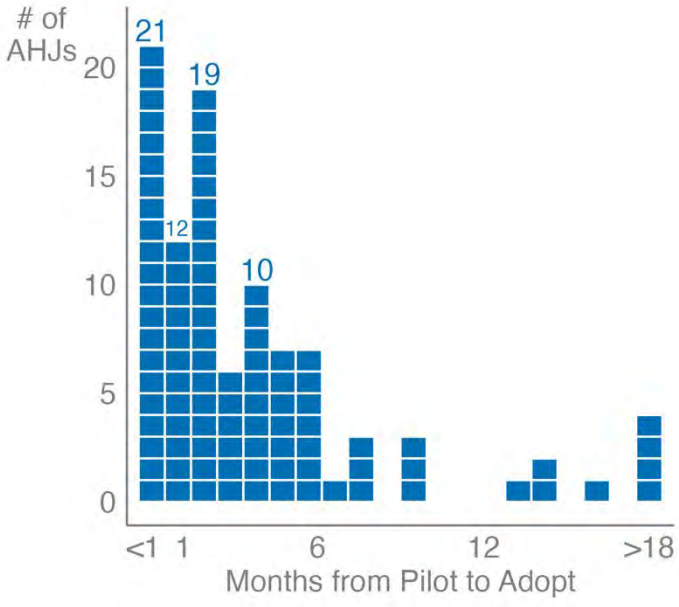


Figure 5. Distribution of AHJ SolarAPP+ implementation timelines from pilot to adoption

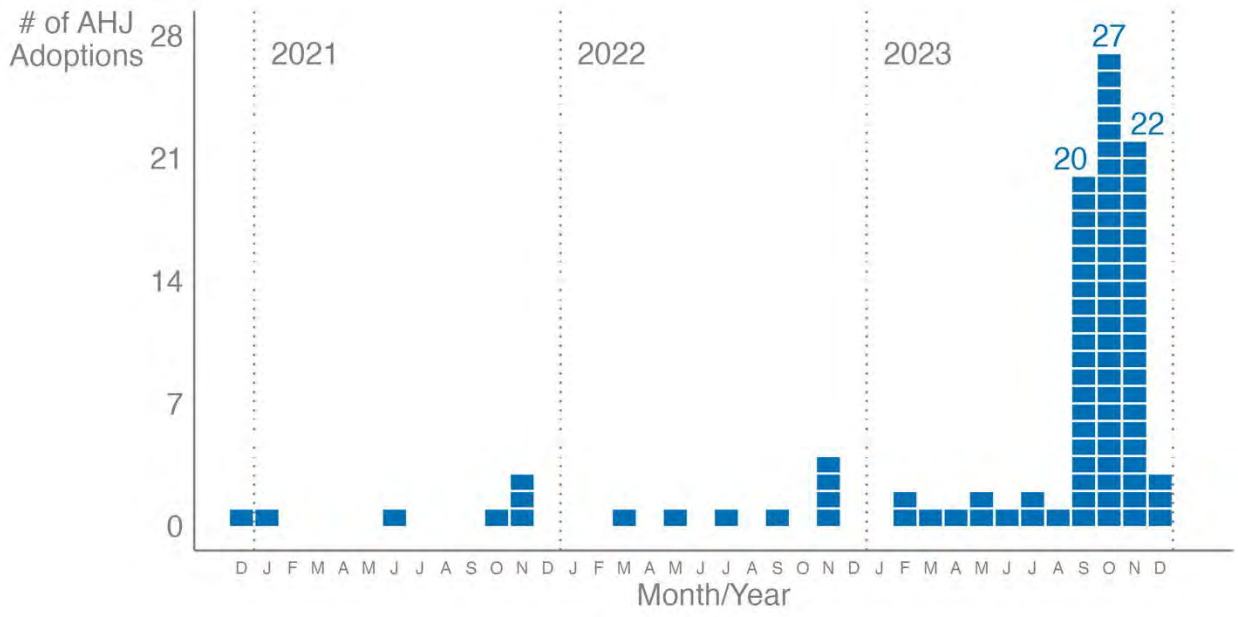


Figure 6. Month of adoption for the 97 AHJs that adopted SolarAPP+ by the end of 2023

NREL documented 215 AHJs that have explored SolarAPP+ but have delayed implementation for various reasons. Figure 7 summarizes the reasons most frequently cited by interested AHJs for delayed implementation. AHJs most commonly cite issues with integrating SolarAPP+ with existing permitting software, issues with payment processing, and conflicts with local codes (e.g., building, electrical, fire, or zoning codes). Note that delayed implementation does not necessarily reflect issues with the SolarAPP+ platform.

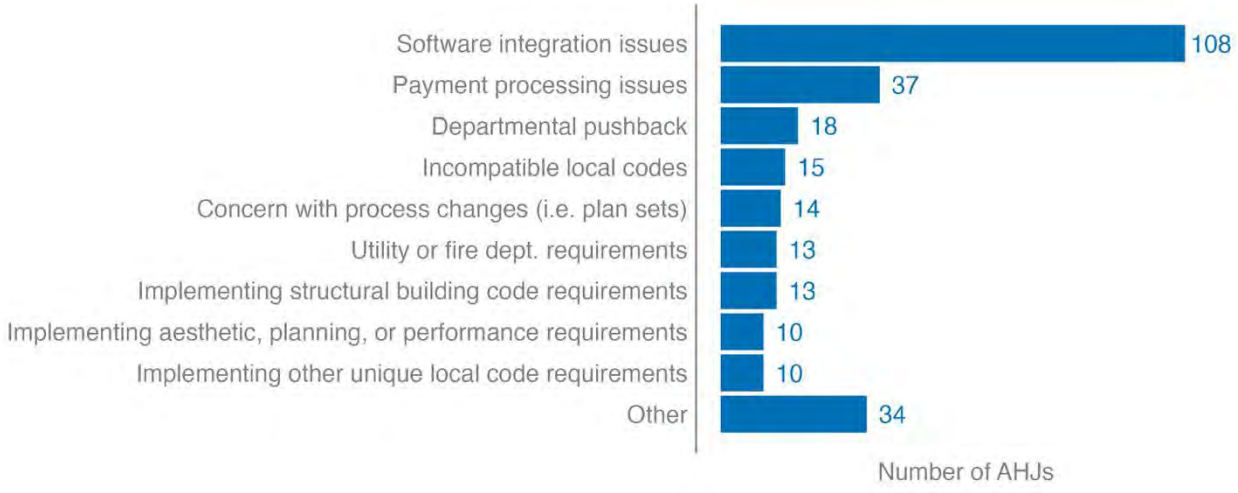


Figure 7. Reasons cited for delays to SolarAPP+ implementation

Note: Some AHJs cite multiple reasons.

Of the more than 1,700 contacted AHJs, 149 AHJs ultimately decided not to adopt SolarAPP+. Figure 8 depicts the reasons provided by these AHJs. Most of these non-adopters are satisfied with their existing permitting systems.

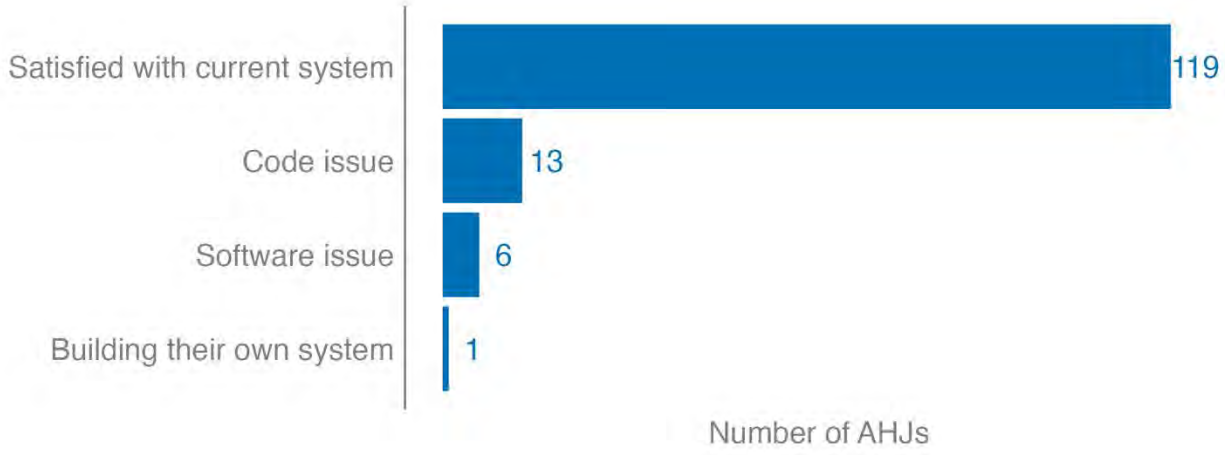


Figure 8. Reasons cited for not adopting SolarAPP+

Note: Some AHJs cite multiple reasons.

3 Performance Review

We review SolarAPP+ performance by comparing metrics for projects processed through SolarAPP+ to those for projects processed through traditional AHJ permitting processes. Performance review data were collected from two sources. First, we pulled data directly from the SolarAPP+ software, including data on projects, installers, AHJ adoption challenges, interested AHJs, and detailed project-level characteristics such as system size, module brand, and information on home electrical upgrades (summary statistics for these project-level characteristics are provided in the appendix). Second, we requested data from 47 AHJs that had adopted SolarAPP+, issued at least 40 SolarAPP+ permits in 2023, and also provided data on permits processed through traditional AHJ permitting processes. Of the 47 AHJs we contacted, 32 were able to provide us with usable data on both SolarAPP+ and traditional permit data. These 32 AHJs provided data, when available, on SolarAPP+ adoption timelines, permit submission dates, permit issuance dates, permit fees, and whether systems included battery storage. Twelve of the AHJs were also able to provide us with the inspection records for all solar permits, including inspection dates, date of final inspection passing, and inspection failure causes. For some analyses, we used the AHJ-provided dates to calculate durations. All durations reported in days are in terms of business days. The degree of data completeness across performance metrics varied by AHJ. The distinct samples used for each analysis are identified in the figure captions.

The term "SolarAPP+ project" refers to any PV or PV+storage system that was entered into SolarAPP+ by a contractor. All SolarAPP+ projects are issued approved system designs/plans, but only some projects are automatically issued a permit via the SolarAPP+ platform, depending on the SolarAPP+ integration pathway chosen by the AHJ.[3] The SolarAPP+ projects that do not receive a permit within SolarAPP+ receive their instant permit from the AHJ after the contractor uploads the SolarAPP+ preapproved system plans in the AHJ's online permitting system. The term "SolarAPP+ permits" refers to both permits automatically issued on the platform and permits issued by the AHJ.

Before proceeding to the results, it is worth noting that our performance review is based on a comparison of outcomes for SolarAPP+ and traditional permits that does not control for potentially confounding factors. Potential differences between the SolarAPP+ and traditional project groups could cause misleading deviations between SolarAPP+ and traditional process durations. For instance, installers that tend to use SolarAPP+ may navigate permitting processes more or less efficiently than installers that use SolarAPP+ less often. Further, the estimated differences between the AHJs in this study are not necessarily representative of the potential impacts of SolarAPP+ in other AHJs. It is possible that the AHJs in this study had more or less efficient traditional permitting processes than an average AHJ prior to implementing SolarAPP+. For these reasons, the reported impacts should be considered approximate impacts of SolarAPP+

[3] SolarAPP+ provides two different implementation pathways for AHJs based on their existing permitting process. AHJs who only accept permits in their traditional process via email, mail, or in person are onboarded using the "standalone" method, where SolarAPP+ also handles their fee collection and issues the final permit. AHJs who use a pre-existing government software system to issue permits are onboarded using the "integrated" method, where SolarAPP+ issues permit documents for upload into their existing software. The contractors then complete their payments in the AHJ's existing software, and that software issues the final permit instantly.

on AHJ permitting process durations. Further research would be required to estimate precise causal impacts of SolarAPP+ on permitting process durations.

3.1 AHJ Permit Volume

In 2023, 668 contractors submitted 18,906 projects and completed 2,879 revisions on these projects (including revisions during inspection) within the SolarAPP+ platform across 150 AHJs (Figure 9). Of those projects, 4,834 were PV+storage projects submitted in 131 AHJs. AHJs with the greatest SolarAPP+ permit volumes were concentrated in Arizona and California (Figure 10).

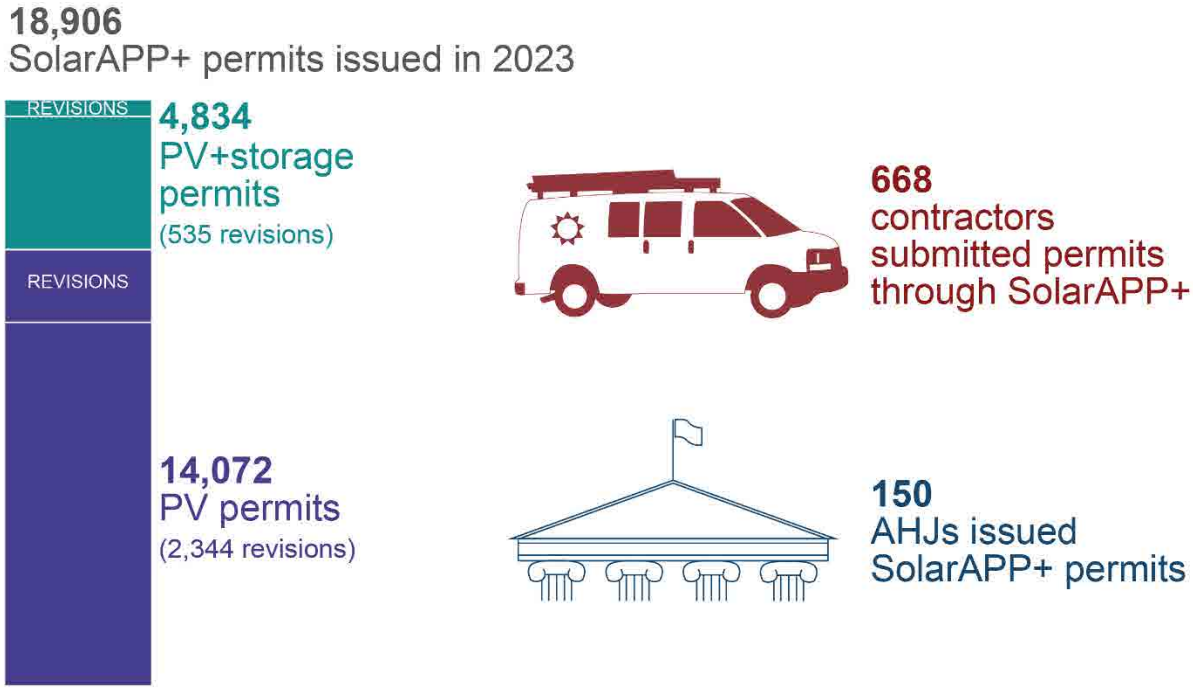


Figure 9. Key statistics on SolarAPP+ permits and revisions in 2023

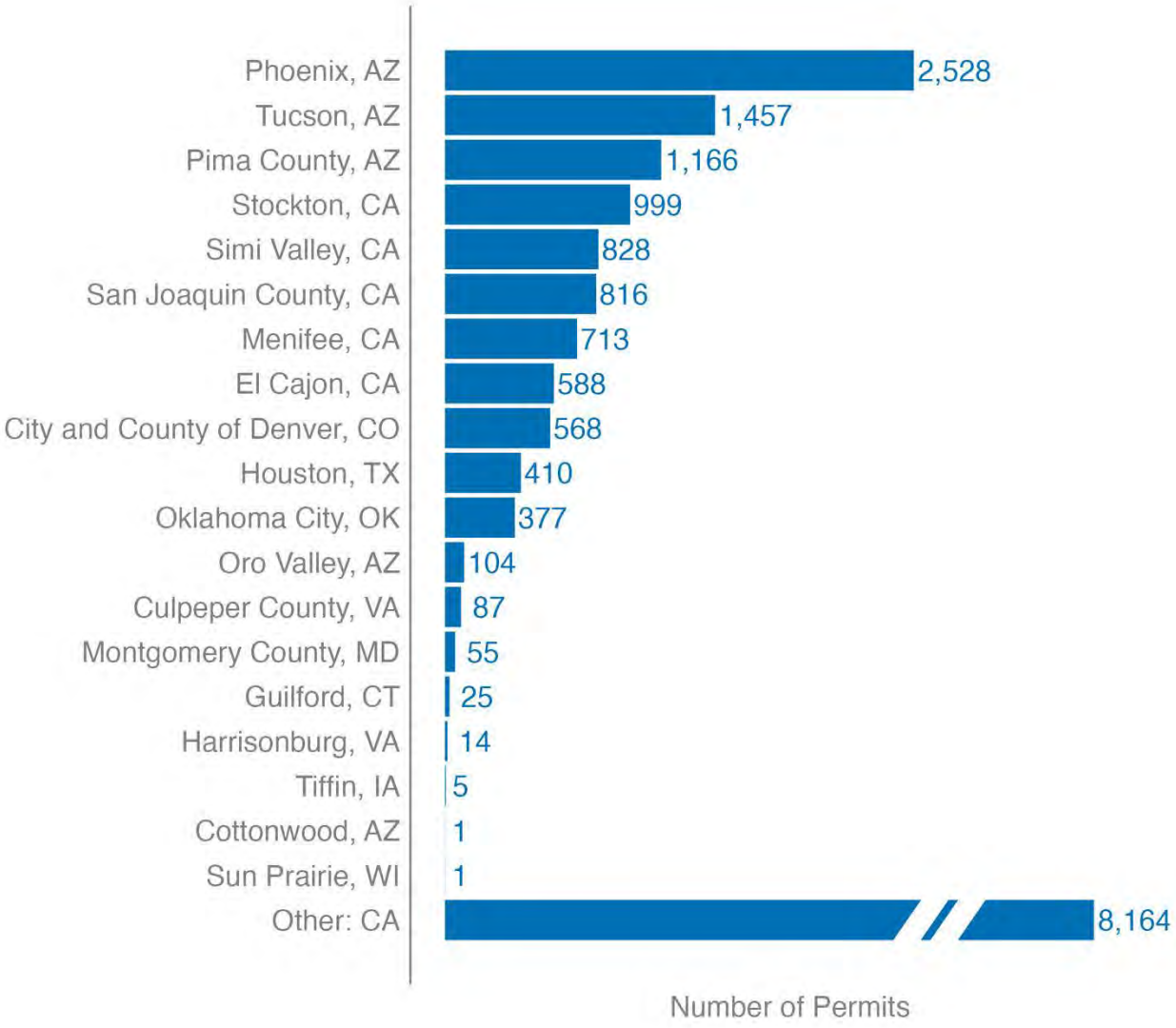


Figure 10. SolarAPP+ permit counts by AHJ

Each AHJ has about 15 installers using SolarAPP+, on average (Figure 11). Participating installers reflect a range of characteristics and installation volumes, confirming that the SolarAPP+ platform is not used exclusively by specific types of installers (Figure 12). The data suggest that a significant share of installers participate in SolarAPP+. For instance, 57 installers submitted SolarAPP+ permits in Tucson, Arizona, in 2023, and data from Barbose et al. (2023) suggest that around 107 installers operated in Tucson in 2022 (the latest year with available data). Although more installers may have been active in Tucson in 2023, the comparison suggests that around half of installers in Tucson used SolarAPP+.

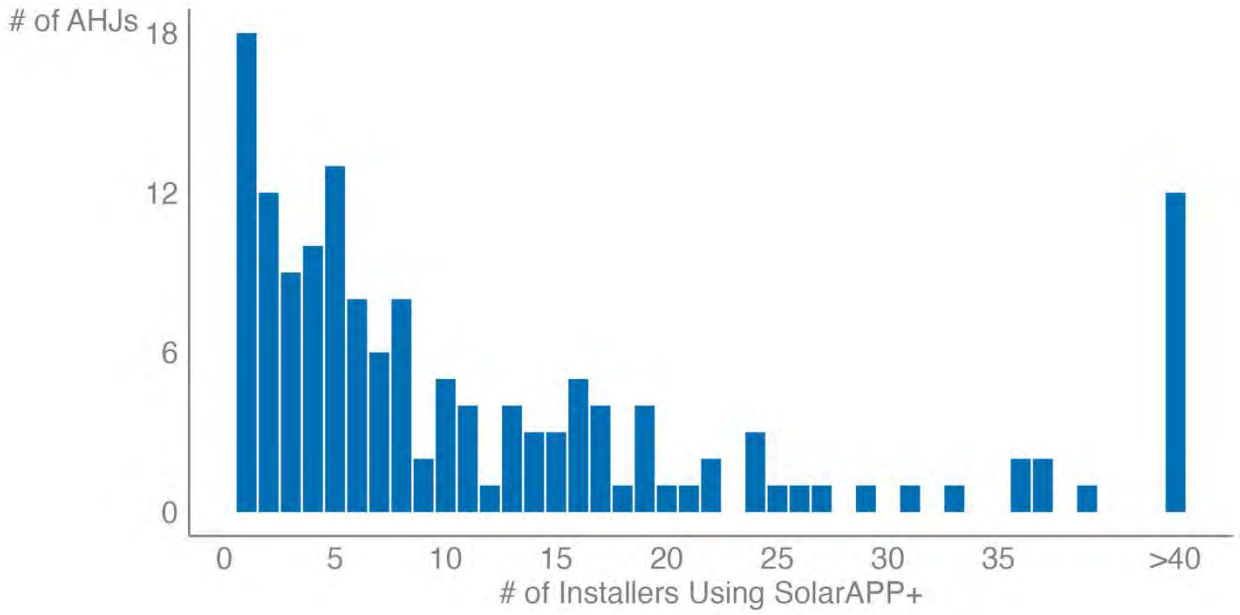


Figure 11. Number of installers using SolarAPP+ by AHJ (2023)

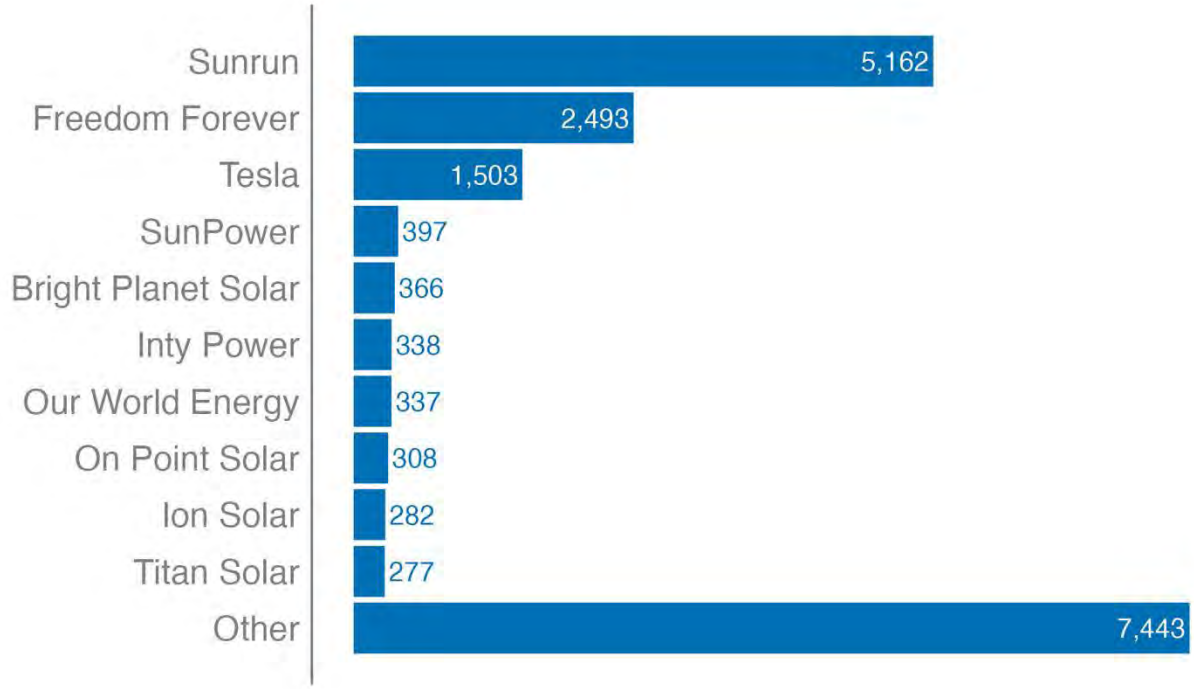


Figure 12. Number of SolarAPP+ projects by participating installer (2023)

After the public launch of SolarAPP+, about 43% of the permits submitted in 2023 in the subsample of 32 AHJs were submitted through the SolarAPP+ platform. The remaining 57% of permits were processed through the AHJs' traditional permitting systems. Figure 13 depicts the distribution of post-launch SolarAPP+ utilization rates by AHJ, showing how utilization rates in most AHJs fall between 20% and 40%, with utilization rates of greater than 80% in several

AHJs. The data suggest that SolarAPP+ utilization rates increase over time. In the 13 AHJs with available data that had publicly launched SolarAPP+ before 2023, monthly utilization rates steadily increased from about 36% in January 2023 to 57% in December 2023 (Figure 14).

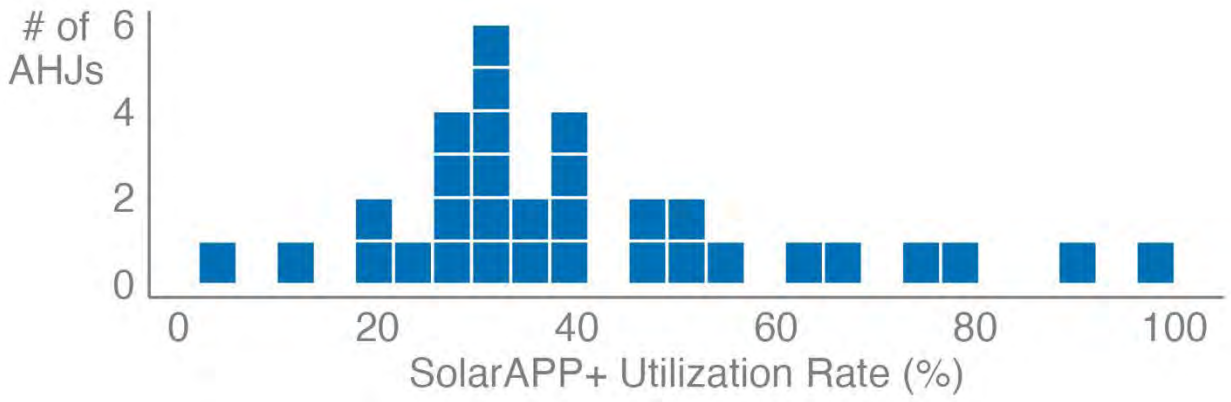


Figure 13. SolarAPP+ utilization rates (2023)

Note: This figure is based on AHJs with at least 30 SolarAPP+ permits submitted in 2023 and available data on traditional permits.

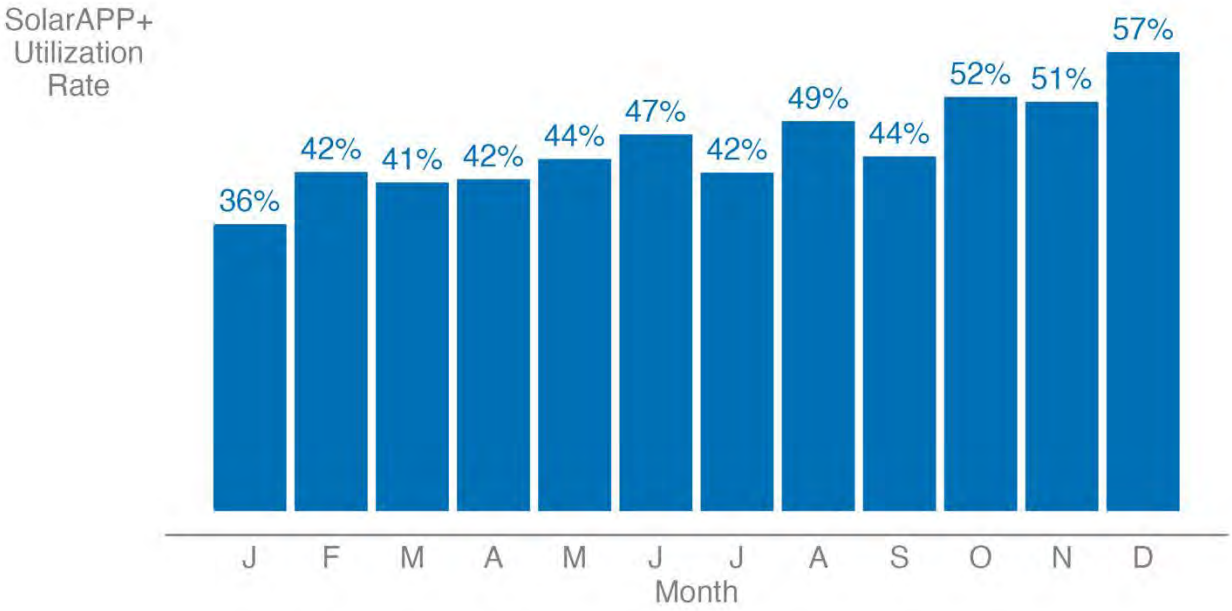


Figure 14. SolarAPP+ utilization rate by month (2023)

Limited to AHJs that publicly launched SolarAPP+ before 2023

3.2 AHJ Permit Review Impacts

Permit review durations refer to the time (in business days) between a permit submission and permit issuance. We compare permit review durations for SolarAPP+ and traditional projects to evaluate the platform's performance during the review stage. In every AHJ, median permit review times for PV-only SolarAPP+ projects were lower than or equal to median review times for traditional permits (Figure 15). The median permit review time for traditional PV-only

projects across all AHJs was 7 days.[4] In contrast, SolarAPP+ facilitates instant permits for code-compliant applications, meaning that the median permit review duration for SolarAPP+ projects was zero days. Review times for PV+storage projects are mostly comparable, with a median review time of 9 days for traditional projects and zero days for SolarAPP+ projects. Median durations represent the permitting experiences of most PV customers. However, some customers experience much longer durations. Around 13% of traditional permits took more than 30 business days, and around 4% took longer than 60 days. SolarAPP+ nearly eliminates these extreme durations, with fewer than 1% of SolarAPP+ permits taking longer than 30 days to be issued.

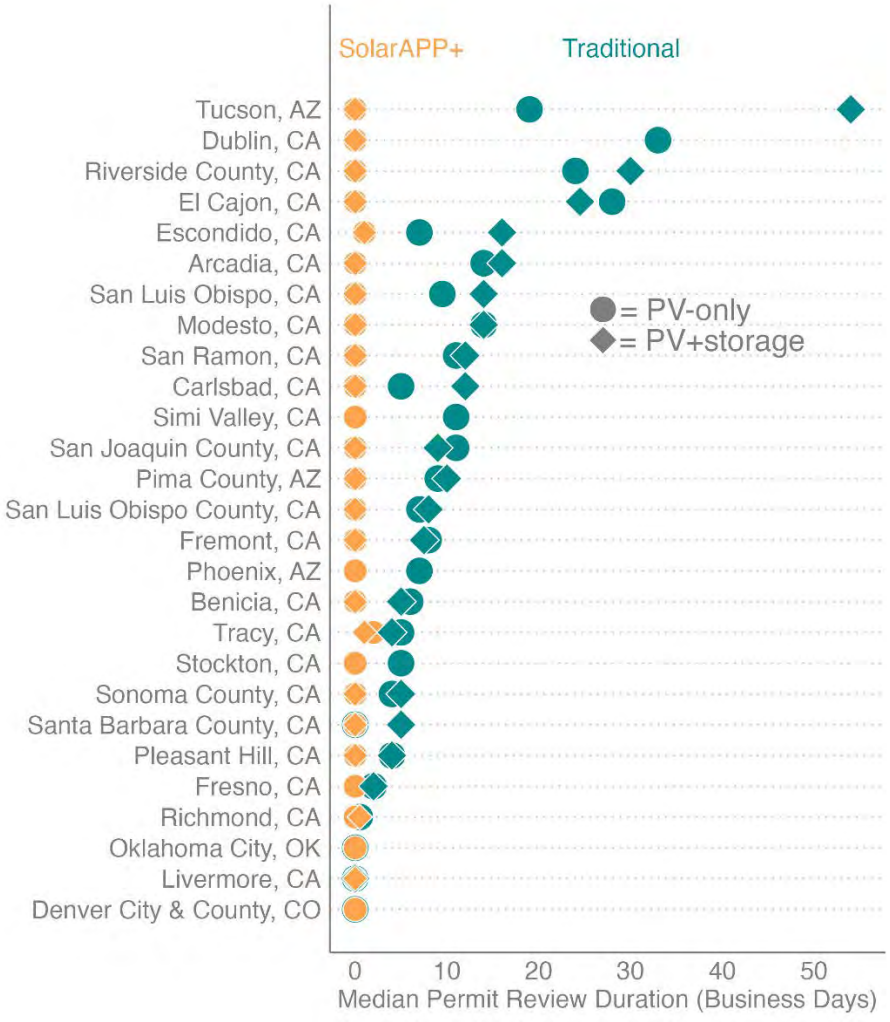


Figure 15. Median permit review times

Note: This figure excludes five AHJs for which duration data were not available for traditional permits.

In addition to reducing permit review durations, the SolarAPP+ platform reduces AHJ staff review time by removing the need for individual permit reviews. The net impact of SolarAPP+ on staff time is influenced by both the time savings from permit reviews and the time required to

[4] Based on feedback from AHJs, these durations reflect timelines for a single permit entry, i.e., they do not include revisions, allowing for an apples-to-apples comparison with SolarAPP+ durations for code-compliant systems.

implement SolarAPP+. According to feedback from AHJs reported in Cook et al. (2022), manual permit reviews require around 25–60 minutes of staff time. Figure 16 depicts the estimated AHJ staff time saved in 2023 by automating permit reviews on the SolarAPP+ platform, assuming reviews take 25–60 minutes. Overall, we estimate that AHJs collectively saved between 9,080 and 21,790 hours of staff time in 2023 by adopting SolarAPP+, including saved time on reviews for permit revisions. This reflects savings for PV-only and PV+storage permits and assuming that every revision must go through AHJ reviews. Estimated staff time savings are the equivalent of about 4–10 full-time employees. Figure 16 depicts the estimated staff time savings in the 10 AHJs with the largest estimated savings in 2023.

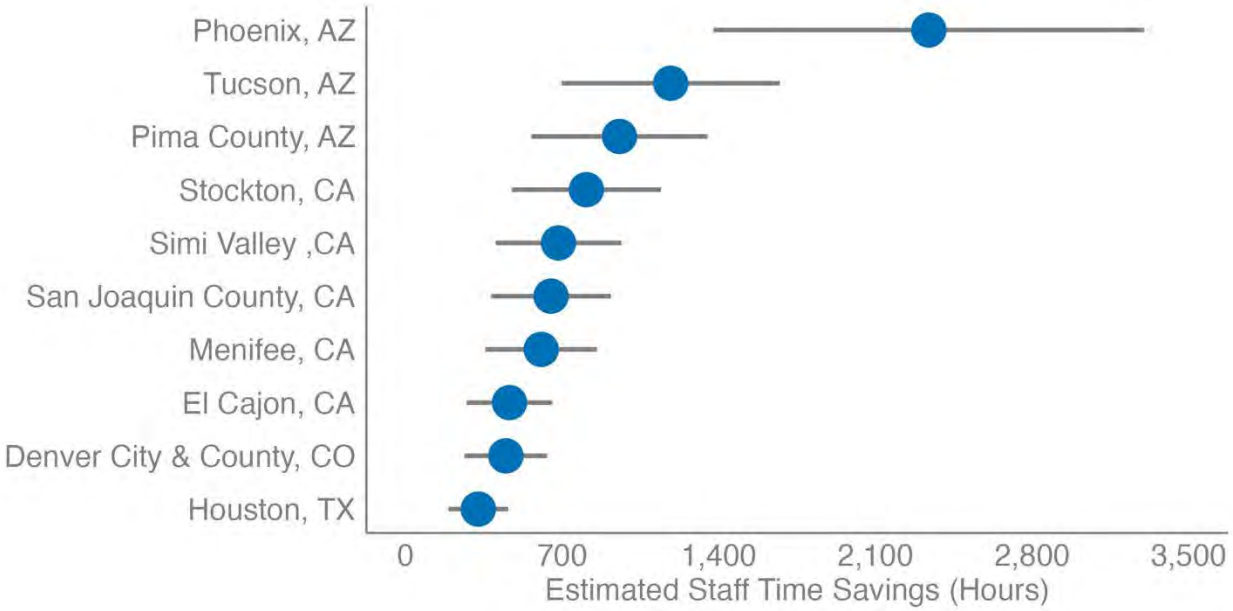


Figure 16. Estimated AHJ staff review time savings (2023) from SolarAPP+ permit processing in the 10 AHJs with the highest estimated savings

Note: The lower and upper bounds of the bars represent staff time savings assuming each review and revision takes between 25 and 60 minutes, respectively, while the points represent the middle of the range (42.5 minutes). These numbers are based on AHJ-provided estimates of permit review time.

3.3 AHJ Inspection Impacts

We define the inspection failure rate as the percentage of projects that failed at least one inspection. Figure 17 depicts inspection failure rates for traditional and SolarAPP+ PV-only projects across 11 AHJs with available data. For PV-only projects, SolarAPP+ inspection failure rates were less than or equal to traditional inspection failure rates in seven of the 11 AHJs in 2023. However, across all 11 AHJs, PV-only inspection failure rates were slightly higher for SolarAPP+ projects than for traditional projects in 2023: about 35% of all SolarAPP+ projects failed an inspection at least once, compared to 29% of traditional projects. That difference is largely driven by Phoenix, the AHJ with the most SolarAPP+ permits and also one of the few AHJs with higher SolarAPP+ inspection failure rates. Excluding Phoenix from the analysis, inspection failure rates were about 23% for SolarAPP+ permits and 26% for traditional permits. As with other analyses, fewer data are available for PV+storage permits, and any analysis of PV+storage data must be treated with caution. With that caveat in mind, the data show that

SolarAPP+ PV+storage inspection failure rates are less than or equal to traditional project rates in the six AHJs with available inspection data for at least 10 records of each type (Figure 18).

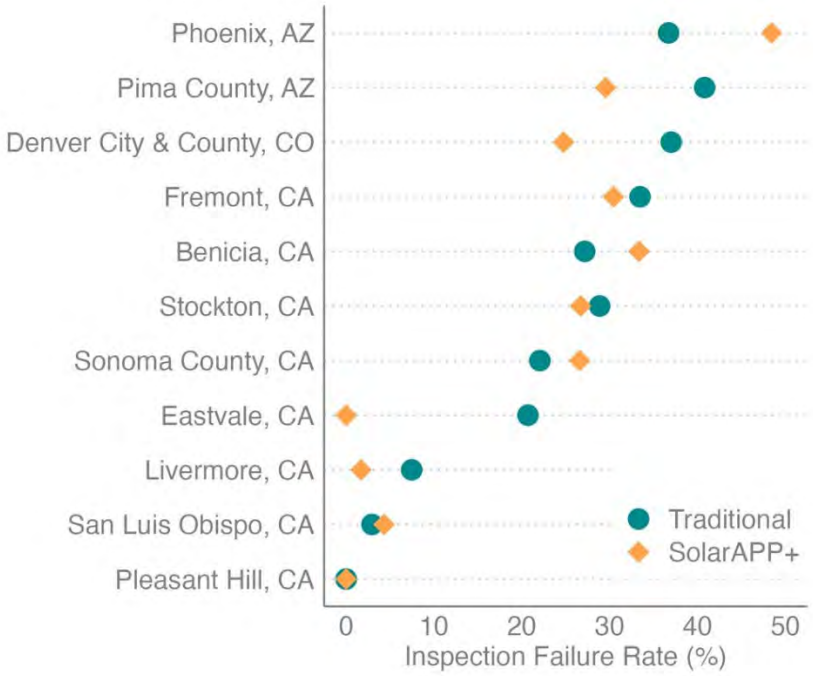


Figure 17. Inspection failure rates for PV-only projects by AHJ (2023)

Note: This figure is limited to AHJs with complete inspection failure data for SolarAPP+ and traditional permits. The figure depicts data from 10,651 inspections (3,455 SolarAPP+, 7,196 traditional).

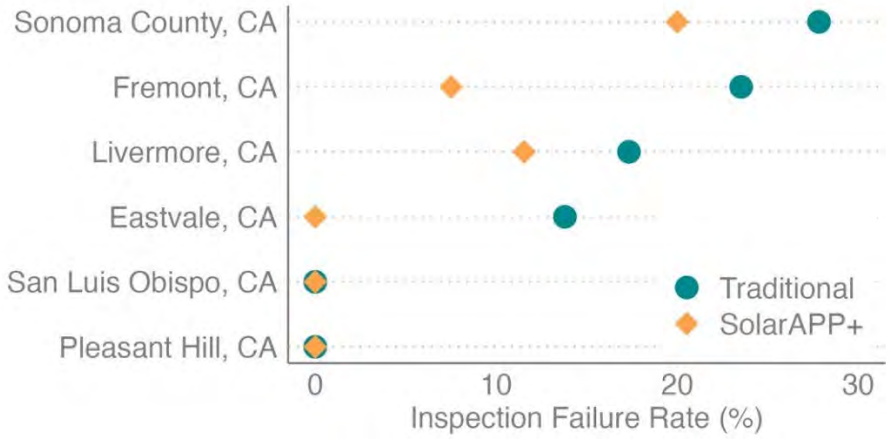


Figure 18. Inspection failure rates for PV+storage projects by AHJ (2023)

Note: This figure is restricted to AHJs with at least 10 inspection records for both SolarAPP+ and traditional permits. The figure depicts data from 682 inspections (156 SolarAPP+, 526 traditional).

While the results are mixed, these results suggest that expedited permitting through SolarAPP+ does not drive any downstream issues with inspections for PV-only or PV+storage projects. Further, the results suggest that—in most AHJs—SolarAPP+ permitting may reduce inspection failure rates. This second result should be treated as a working hypothesis; it is possible that the

differences in inspection failure rates reflect preexisting differences between installers that do and do not use SolarAPP+. Further research is required to understand the impacts of SolarAPP + on inspection failure rates.

In addition to tracking the volume of SolarAPP+ inspection failures, we also tracked the reasons for inspection failure (Figure 19). 78% of the identified failures related to a work quality issue, meaning that the system was not installed per the code, either in isolation (71%) or accompanied by other issues (6%). About 13% of failures related to rescheduling, primarily because the homeowner or contractor was not available at the scheduled inspection time. Of the remaining inspection failures, a combined 17% were related to SolarAPP+ (install did not match the SolarAPP+ plan or inspection checklist was not on site). It is possible that more contractor education could result in fewer inspection failures of these types, thereby further improving SolarAPP+ inspection performance.

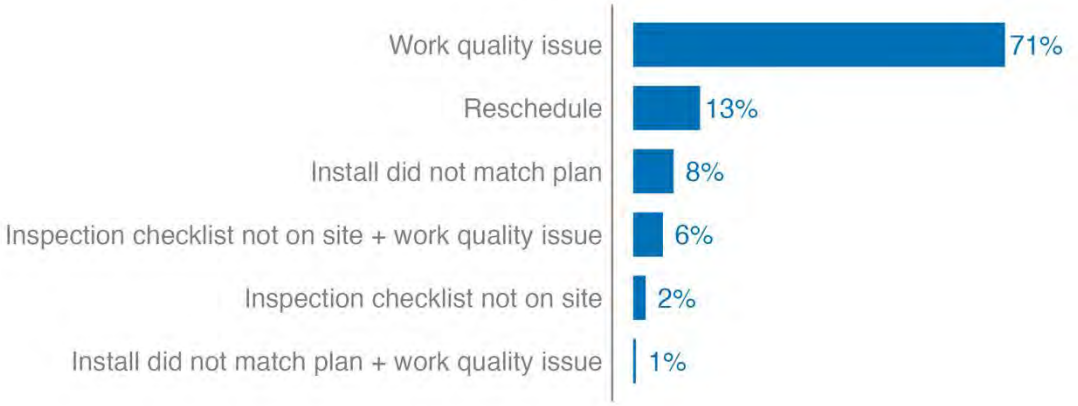


Figure 19. Known reasons for inspection failures among SolarAPP+ projects

3.4 Solar Adoption Timeline Impacts

In the previous two sections, we explored the impacts of SolarAPP+ at specific stages of the solar adoption timeline. Here, we explore the full timeline impacts of SolarAPP+, from permit submittal to final inspection. Across 27 AHJs with available data for PV-only projects,[5] the median duration from permit submission to final passed inspection was 33 business days for SolarAPP+ permits and 47.5 business days for traditional permits, suggesting that SolarAPP+ reduces permit-to-inspection timelines by around 14.5 days or about 31% (Figure 20). Similarly, across 19 AHJs with available data for PV+storage projects, the median permit-to-inspection duration was 29 days for SolarAPP+ permits and 52 days for traditional permits, suggesting that SolarAPP+ reduces permit-to-inspection timelines by around 44% for PV+storage permits.

[5] These subsamples refer to AHJs for which we have available data for complete durations for both SolarAPP+ and traditional permits.

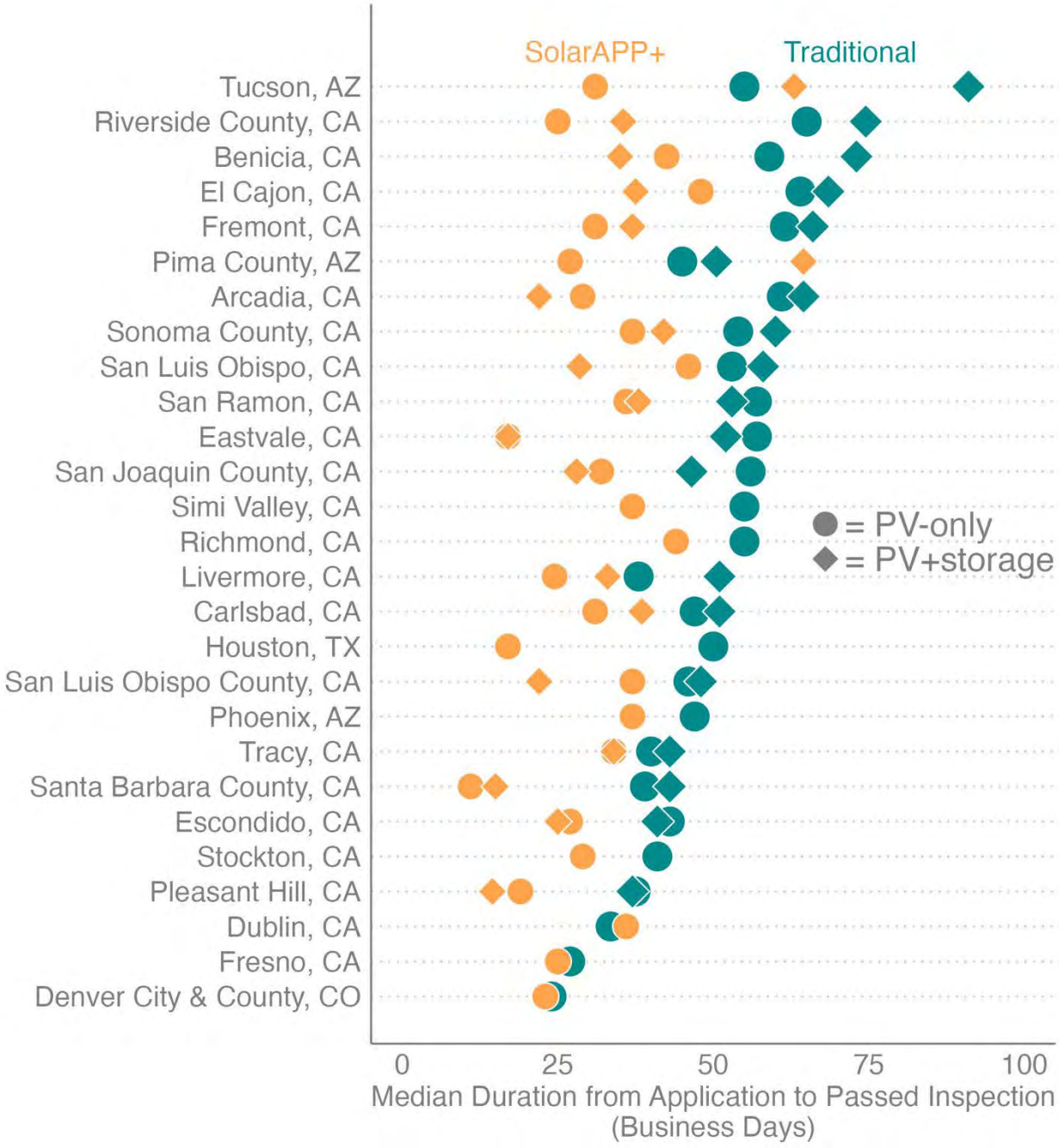


Figure 20. Median project time from permit submission to passed inspection by AHJ (2023)

Note: This figure excludes five AHJs for which duration data were not available for both SolarAPP+ and traditional permits.

Figure 21 depicts the estimated total impact of the SolarAPP+ platform in terms of reduced days for the 27 AHJs with available data. The total impact is a function of the number of permits processed and the estimated permit-to-inspection duration reduction in each AHJ. The figure shows that SolarAPP+ is estimated to have accelerated permitting processes by thousands of days in 2023, with savings of well over 10,000 days in some large AHJs. Across the 27 AHJs,

the total estimated acceleration is 154,000 business days. As a reminder, these results are indicative of the total impact of SolarAPP+ on permit-to-inspection durations, but further research would be required to estimate the precise causal impact of SolarAPP+ on total time savings.

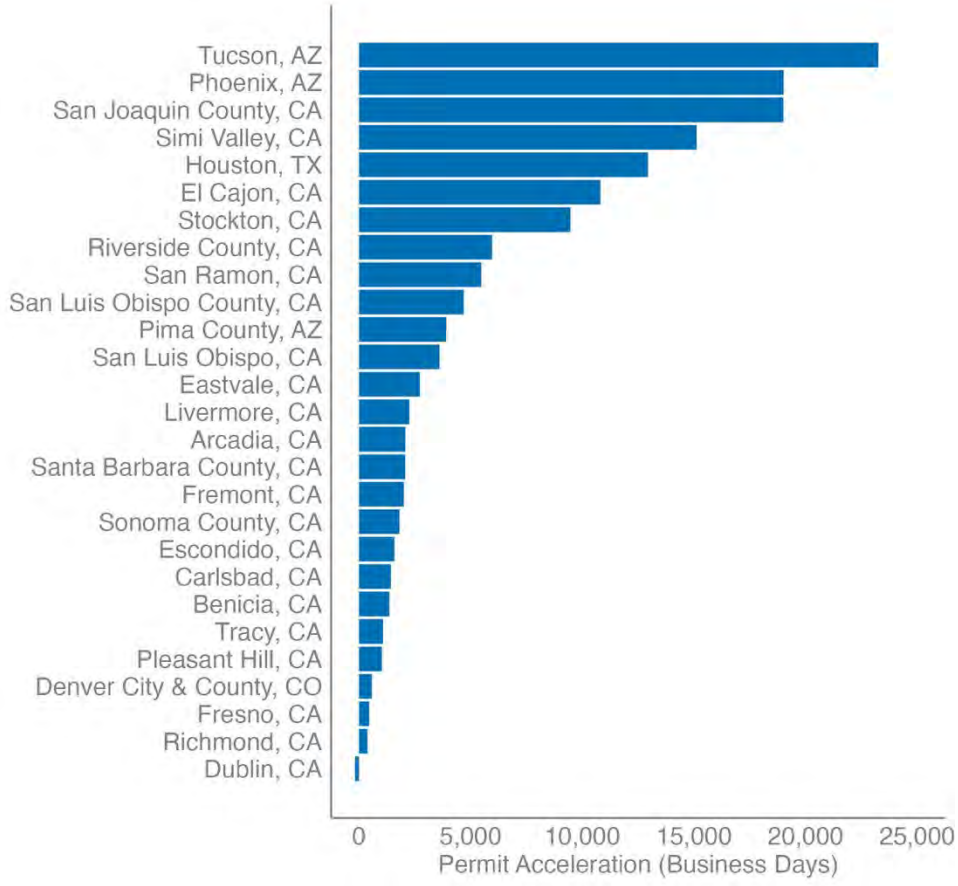


Figure 21. Total estimated acceleration of project timelines (permit submission to passed inspection) across AHJs

4 SolarAPP+ Estimated Impacts

The impact of SolarAPP+ on PV permitting processes may translate to broader impacts on the rooftop PV market. In this section, we explore the potential broader impacts of SolarAPP+ adoption in three dimensions: impacts on PV costs/prices, impacts on PV deployment, and AHJ benefits. We estimate ranges of potential impacts based on lower- and upper-bound assumptions in each of the three dimensions. We estimate the impacts of the 18,906 SolarAPP+ permits issued in 2023.

As in Section 3, we note here that the estimated impacts in this section should be interpreted as indicative of estimates under reasonable assumptions. Again, some estimated impacts may be sensitive to confounding factors that correlate with SolarAPP+ utilization. One possibility is that installers that use SolarAPP+ were already more efficient (i.e., quicker through permitting and inspection) than installers that tend to use traditional permits, in which case some of the estimated impacts of SolarAPP+ are in fact attributable to these preexisting differences. We have no specific reason to suspect that such confounding factors correlate with SolarAPP+ utilization, but the analysis that follows should be interpreted in light of that potential limitation.

4.1 Installation Costs

SolarAPP+ adoption could reduce PV installation costs and prices. We estimate the total impact on costs based on potential savings in permitting fees, permitting costs, cancellation costs, and inspection costs.

4.1.1 Permitting Fees

SolarAPP+ could reduce AHJ budgets for staff time to process PV permits and allow AHJs to reduce PV permitting fees (Plaisted 2022; Cook et al. 2023). Fee savings in AHJs that have already adjusted their fees range from $6–$251 per permit (Cook et al. 2023). Plaisted (2022) estimated fee savings of $215 per permit for PV-only systems and $390 per permit for PV+storage systems. Here, we assume that SolarAPP+ adoption reduces net permitting fees in the range of $50–$250.

4.1.2 Permitting Costs

SolarAPP+ adoption could reduce permitting compliance costs by facilitating the permitting process. Permitting costs can be direct, such as installer time spent preparing permitting applications for specific projects, and indirect, such as installer time spent learning how to navigate different permitting requirements across different AHJs. The Solar Energy Industries Association (SEIA) estimates that direct permitting costs (including inspection) are around $0.13/W, while full (direct and indirect) permitting costs are about $1/W (SEIA 2019). Our best proxy for the impacts of SolarAPP+ on these costs is the estimated 31% reduction in permitting timelines associated with SolarAPP+ estimated in Section 3.4. Assuming SolarAPP+ has a similar impact on costs, that equates to a permitting cost reduction of around $0.04–$0.31/W, which we use to define our lower- and upper-bound assumptions for SolarAPP+ permitting cost reductions.

Our assumed range is comparable to, if slightly lower than, the estimated range of $0.20–$0.57/W in permitting cost savings from SolarAPP+ that was estimated in an independent analysis (Plaisted 2022).

Further, Plaisted (2022) estimated substantially higher direct and indirect permitting cost savings for PV+storage projects of about $0.4–$1.1/W. Plaisted's estimate suggests that SolarAPP+ could play a particularly important role in mitigating permitting costs for PV+storage systems, which tend to be higher than for PV-only systems. Further research is required to characterize the role of SolarAPP + more precisely in PV+storage permitting.

4.1.3 Cancellation Costs

Estimates across the literature suggest that around 11%–33% of PV customers cancel their contracts (Liao 2020; Cook et al. 2021; Cruce et al. 2022).[6] Customer cancellations leave installers with costs that must be recouped through higher prices on successful projects. SolarAPP+ could reduce PV costs by reducing permitting delays and thus reducing cancellation rates. Cruce et al. (2022) estimate that these costs amount to about $0.1/W for a typical system. We assume that SolarAPP+ reduces customer cancellation costs by 2%–5% (see Section 4.2.1), amounting to an additional $0.002–$0.005/W reduction in PV installation prices.

4.1.4 Inspection Costs

SolarAPP+-permitted systems are more likely to pass inspections than other systems in most AHJs (see Section 3.3). This impact remains inconsistent across AHJs and uncertain: It is possible that the measured difference reflects preexisting differences between installers that use SolarAPP+ and those that do not. Insofar as SolarAPP+ improves inspection outcomes, installers would save money by avoiding repeated inspections. However, these cost savings are unlikely to be substantial. Assuming that inspection failures require 8 hours of installer or electrician time to address issues and repeat inspections,[7] assuming a wage of $25.50/hour,[8] each reinspection costs around $200. For those savings to make a material impact, SolarAPP+ would need to lead to significantly fewer reinspections. Excluding Phoenix, SolarAPP+-permitted systems failed inspections 4 percentage points less frequently than other systems in 2023 (see Section 3.3), which only equates to about $8 in savings per installed system. Given the uncertainties and potential minor impact of this cost, we exclude this factor from our analysis below.

4.1.5 Total Installation Cost Impacts

To convert $/W savings estimates to total savings, we multiply the $/W estimates by 6 kW, the median system size of SolarAPP+-permitted systems (see Appendix A.1). The total assumed per-install cost savings range from $300–$2,100. For perspective, those estimates reflect a 2%–13% cost reduction relative to residential PV system cost benchmarks (Ramasamy et al. 2023). We

[6] The wide range may reflect methodological differences and how cancellations are defined, as discussed in Cruce et al. (2022).
[7] Typical inspections last around 20–30 minutes. Most of the time assumed here is to address the inspection failure issue.
[8] Based on a mixed wage of installers (median wage of $22/hour: Palmer et al. 2023) and electricians ($29/hour based on Bureau of Labor Statistics data).

then multiply these system-level savings by the number of SolarAPP+ permits issued in 2023. Table 1 summarizes the three cost savings components. In total, we estimate that SolarAPP+ permitting avoided around $6M–$41M in permitting-related costs in 2023. The wide range primarily reflects the uncertainty in the degree to which SolarAPP+ permitting can reduce both direct and indirect permitting costs.

Table 1. Estimated Cost Savings ($M) From SolarAPP+ Implementation

Cost Savings	Lower Bound	Upper Bound
Permitting fees	0.9	4.7
Permitting costs	4.5	35.2
Cancellation costs	0.2	0.6
Total	**$5.6M**	**$40.5M**

4.2 Deployment

We explore potential impacts of SolarAPP+ on deployment due to avoided customer cancellations, reduced costs, and improved customer experiences.

4.2.1 Avoided Cancellations

As noted in Section 4.1.3, around 11%–33% of PV customers cancel their contracts. Cruce et al. (2022) estimate that about 2% of those cancellations occur during permit review. In our lower-bound case, we use that estimate to assume that SolarAPP+ reduces customer cancellations by 2% by expediting permit reviews. That share likely understates the role of permitting in driving customer cancellations, given that installers cite permitting delays as the key driver of cancellations (Cook et al. 2021) and permitting-related delays can begin before a permit is submitted (Plaisted 2022). We therefore assume that SolarAPP+ reduces customer cancellations by 5% in our upper-bound case. Finally, based on the range of estimates from the literature, we assume that around 22% of contracts are canceled. Under these assumptions, SolarAPP+ adoption would increase deployment by 0.4%–1.1% above background levels by avoiding cancellations.

4.2.2 Deployment Impacts From Reduced Prices

In Section 4.1, we estimated that SolarAPP+ reduces PV costs by $300–$2,100 per install. In competitive markets, most of those cost reductions will be passed through to customers as lower prices. Assuming that 90% of cost reductions are passed through to customers, a $300–$2,100 cost reduction equates to roughly a 2%–17% price reduction relative to post-incentive prices for typical systems.[9] Gillingham and Tsvetanov (2019) estimate that rooftop PV demand declines by about 65% for each doubling in price, meaning that a 2%–17% price reduction from SolarAPP+ equates to roughly a 2%–11% increase in demand.[10]

[9] Assuming a median-sized 6-kW system at the NREL benchmark price of $2.68/W that receives at least a 30% incentive from the federal investment tax credit.

[10] The Gillingham and Tsvetanov estimate may be conservative. Ros and Shetty Sai (2023) estimate rooftop PV price elasticities on the order of 100%–300%.

Plaisted (2022) argues that SolarAPP+-related price reductions would have a particularly substantial impact on PV deployment among low- and moderate-income (LMI) households. The rationale is that LMI customers are more price sensitive, such that a given change in price would have a larger impact on LMI deployment than on deployment among more affluent households. This is a plausible hypothesis, but the precise impact of price reductions on LMI deployment requires further research. LMI households face numerous barriers to adoption unrelated to price, such as lower homeownership rates. Further, many LMI adopters lease rather than purchase PV systems, such that the net impact of cost reductions on LMI PV prices could be muted. The specific impacts of SolarAPP+ on LMI deployment is a potential area for further research.

4.2.3 Improved Customer Experiences

Some households base their rooftop PV adoption decisions on the previous experiences of other adopters (Wolske et al. 2020). In many cases, households actively consult with previous adopters (Sigrin et al. 2017), and paid referrals (i.e., installers paying previous adopters to refer other customers) are common (Mond 2017). Insofar as SolarAPP+ facilitates PV permitting and improves customer experiences, customers of installers who use SolarAPP+ may be more likely to recommend adoption to their peers. This potential impact is highly uncertain and requires further research. We therefore exclude the impact from our lower-bound case. In our upper-bound case, we assume that improved customer experiences result in 0.05 additional referrals per SolarAPP+ adopter, roughly a 10% increase over background referral rates (Mond 2017).

4.2.4 Total Impacts

Table 2 summarizes the three deployment impact components. The total estimated impacts are a 2%–17% increase in deployment, equating to an additional 380–3,260 additional installs. That is, we estimate that the existence of the SolarAPP+ platform *increased* rooftop PV deployment by around 2%–17% in 2023 relative to what would have otherwise been deployed in the same year. For comparison, Plaisted (2022) estimates a 7%–25% increase in deployment for middle-income customers, and a 19%–100% increase for low-income customers.

Table 2. Assumed Deployment Impacts From SolarAPP+ Implementation

Deployment Impact	Base Case	Advanced Case
Reduced cancellations	80	210
Reduced prices	300	2,100
Improved customer experience	0	950
Total	**380**	**3,260**

4.3 AHJ Benefits

SolarAPP+ could benefit AHJs in at least three ways: permitting cost savings, electricity bill savings for AHJ residents, and progress toward sustainability goals.

4.3.1 Permitting Cost Savings

By automating PV permitting, SolarAPP+ frees up AHJ staff time for other AHJ services. Available data suggest that AHJs save around 25–60 minutes of staff time per permit, on average, equating to around 7,900–18,900 hours saved for SolarAPP+ AHJs in 2023. Based on

an average wage of $21.9/hour for administrative staff (BLS 2023), the value of the saved time in 2023 is about $173,000–$414,000.

4.3.2 Electricity Bill Savings

While household electricity bill savings may not directly benefit an AHJ, bill reductions from automatic permitting are a type of AHJ service. These bill savings accrue from the accelerated timelines associated with SolarAPP+. In Section 3.4, we estimate that SolarAPP+ systems are permitted and installed 14.5 days faster than other systems, at the median. To estimate a rough heuristic of the bill savings accruing from that acceleration, consider that a typical household uses around 30 kWh per day and pays a rate of around $0.2/kWh.[11] Under those simplifying assumptions, a typical household spends about $87 for 14.5 days of electricity use. In the summer months, PV systems could offset nearly that full amount, although rate reforms in states such as California mean that PV systems cannot fully offset those charges. To be conservative, we assume that a typical customer saves $50 from the accelerated PV timeline. Applying that heuristic, SolarAPP+ PV adopters saved around $945,000 in 2023 due to the accelerated timelines from SolarAPP+ permitting.

4.3.3 Progress Toward Sustainability Goals

Many AHJs have set sustainability goals, such as achieving target rates of decarbonization by specified dates (Watts et al. 2017). SolarAPP+ adoption could help AHJs achieve their sustainability goals more quickly in at least three ways:

- As discussed in Section 4.2, we estimate that SolarAPP+ increased rooftop PV deployment by about 340–3,150 systems in 2023. That incremental deployment could contribute directly to the clean energy deployment goals of those AHJs. The additional deployment would also accelerate decarbonization. Likewise, accelerated permitting means that PV systems come online faster and begin to abate emissions sooner. Assuming that the 18,906 SolarAPP+-permitted systems came online 14.5 days faster than they otherwise would have, that equates to adding 274,000 days of emissions abatement. Rooftop PV decarbonization benefits are estimated to be on the order of 500 kg CO_2/year avoided per installed system (Zheng et al. 2021),[12] varying with the underlying emissions intensities of the grid in different AHJs. Using that estimate, the total emissions reduction in 2023 from added and accelerated deployment due to SolarAPP+ was around 0.5M–2.0M tCO_2 in 2023. For context, that is roughly the equivalent of offsetting the emissions from the electricity use of 110,000–380,000 homes (EPA n.d.).
- Permitting and inspection cost savings from SolarAPP+ would free up AHJ resources, some of which could be dedicated to clean energy programs.

[11] The U.S. average is about $0.16/kWh; we adjust this slightly higher to account for higher rates in California ($0.27/kWh on average) (EIA 2023).
[12] Zheng et al. (2021) estimate emissions benefits of 110–570 kg CO_2/year for a 4-kW system. Adjusting that for the median SolarAPP+ system (6 kW) and taking the middle of the range yields an estimate of 510 kgCO_2/year.

- SolarAPP+ adoption could help AHJs achieve recognition of their clean energy programs. To provide one tangible example, SolarAPP+ (or similar instant permitting) has been recognized as a key component for SolSmart designation, a program that recognizes AHJs with outstanding achievement in PV permitting. In 2024, two SolarAPP+ adopters (Fremont, California, and Sun Prairie, Wisconsin) were awarded some of the program's first platinum designations.

References

Barbose, G., N. Darghouth, E. O'Shaughnessy, S. Forrester. 2023. *Tracking the Sun (2023 Edition)*. Berkeley, CA: Lawrence Berkeley National Laboratory.

BLS. 2023. *Occupational Employment and Wage Statistics.* Washington, D.C.: Bureau of Labor Statistics.

Burkhardt, J., R. Wiser, N. Darghouth, C.G. Dong, J. Huneycutt. 2015. "Exploring the impact of permitting and local regulatory processes on residential solar prices in the United States." *Energy Policy* 78: 102–112.

Cook, J.J., J. Cruce, E. O'Shaughnessy, K. Ardani, R. Margolis. 2021. "Exploring the link between project delays and cancelation rates in the U.S. rooftop solar industry." *Energy Policy* 156: 112421.

Cook, J.J., E. O'Shaughnessy, K. Xu, S. Jena, M. Sana Qasim, S. Crew. 2022. *SolarAPP+ Performance Review: 2021 Data*. Golden, CO: NREL. NREL/TP-6A20-83046.

Cook, J., R. Yu, K. Xu, S. Jena, T. Rivard, J. de la Paz. 2023. *SolarAPP+ Performance Review (2022 Data)*. Golden, CO: NREL. NREL/TP-6A20-85827.

Cruce, J.R., E. O'Shaughnessy, J.J. Cook. 2022. *Evaluating the Impact of Residential Solar Contract Cancellations in the United States*. Golden, CO: NREL. NREL/TP-6A20-80626.

Dong, C., R. Wiser. 2013. "The impact of city-level permitting processes on residential photovoltaic installation prices and development times: An empirical analysis of solar systems in California cities." *Energy Policy* 63: 531–542.

EIA. 2023. *Average Price of Electricity to Ultimate Customers by End-Use Sector*. Washington, D.C.: U.S. Energy Information Administration.

EnergySage. 2024. *Solar & Storage Marketplace Report 2023*.

EPA. n.d. "Greenhouse Gases Equivalencies Calculator - Calculations and References." U.S. Environmental Protection Agency. Accessed 3/21/2024.

Fekete, E.S., J.R. Cruce, S. Dong, E. O'Shaughnessy, J.J. Cook. 2022. *A Retrospective Analysis of Distributed Solar Interconnection Timelines and Related State Mandates*. Golden, CO: NREL. NREL/TP-6A20-81459.

Gillingham, K., T. Tsvetanov. 2019. "Hurdles and steps: Estimating demand for solar photovoltaics." *Quantitative Economics* 10 (2019): 275–310.

Liao, Y. 2020. "Weather and the decision to go solar: evidence on costly cancelations." *Journal of the Association of Environmental and Resource Economists* 7: 1–33.

Mond, A. 2017. *U.S. Residential Solar PV Customer Acquisition 2017*. Wood Mackenzie.

O'Shaughnessy, E., S. Dong, J.J. Cook, J. Cruce, K. Ardani, E. Fekete, R. Margolis. 2022. "Effects of local permitting and interconnection requirements on solar PV installation durations." *Energy Policy* 161: 112734.

Palmer, A., E. Gillland, M. Hernandez. 2023. *National Solar Jobs Census 2022*. Interstate Renewable Energy Council.

Parsons, S., N. Josefowitz. 2020. *A No-Cost Rooftop Solar Stimulus: How streamlining residential solar installations can jumpstart a green economic recovery*. San Francisco, CA: San Francisco Bay Area Planning and Urban Research Association.

Plaisted, J.R. 2022. *Potential of SolarAPP+ Automated Permitting to Reduce Costs & Increase Solar Adoption in California*. Flagstaff Research.

Ramasamy, V., J. Zuboy, M. Woodhouse, E. O'Shaughnessy, D. Feldman, J. Desai, A. Walker, R. Margolis, P. Basore. 2023. *U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2023*. Golden, CO: NREL. NREL/TP-7A40-87303.

Ros, A.J., S. Shetty Sai. 2023. "Residential rooftop solar demand in the U.S. and the impact of net energy metering and electricity prices." *Energy Economics* 118:106491.

SEIA. 2019. *Lowering Soft Costs – a Major Opportunity for Growth*. Solar Energy Industries Association.

Sigrin, B., et al. 2017. *Understanding the Evolution of Customer Motivations and Adoption Barriers in Residential Solar Markets*. Golden, CO: NREL.

Stanfield, S., Schroeder, E., Culley, T., 2012. *Sharing Success: Emerging Approaches to Efficient Rooftop Solar Permitting.* Interstate Renewable Energy Council.

Watts, M., et al. 2017. *Focused acceleration: A strategic approach to climate action in cities in 2030*. C40 Cities.

Williams, J., J.J. Cook, J.R. Cruce, K. Xu, S. Crew, M. Qasim, M. Miccioli. 2022. *SolarAPP+ Pilot Analysis: Performance and Impact of Instant, Online Solar Permitting*. Golden, CO: NREL. NREL/TP-6A20-81603.

Wolske, K., K.T. Gillingham, P.W. Schults. 2020. "Peer influence on household energy behaviours." *Nature Energy* 5: 202–212.

Zheng, J., Z. Lin, E. Masanet, R. Deshmukh, S. Suh. 2021. "Lifecycle cost and carbon implications of residential solar-plus-storage in California." *iScience* 24: 103492.

Appendix. SolarAPP+ Project Design Characteristics

The SolarAPP+ platform provides a new data source for rooftop PV system characteristics. In this appendix, we describe SolarAPP+ solar and battery system characteristics and discuss how SolarAPP+ projects compare to the broader rooftop PV and battery storage markets. All numbers and figures in this section reflect cumulative data, i.e., including projects permitted before 2023.

A.1 System Size

The median system size for SolarAPP+ PV-only projects is about 6 kW, ranging from 0.2–29 kW (Figure 22).[13] The system sizes are comparable to sizes in the broader rooftop PV market, as indicated by the 7-kW median for systems installed in 2022 estimated by Barbose et al. (2023). Projects in the PV+storage pilot tend to be similarly sized, with a median PV system size of 6 kW. Further, most batteries in the PV+storage pilot have similar rated storage capacities, reflecting the standardized rated output of the limited number of battery products used in the pilot. Out of 40 PV+storage projects with available data, 35 projects had 13.5 kWh of storage capacity.

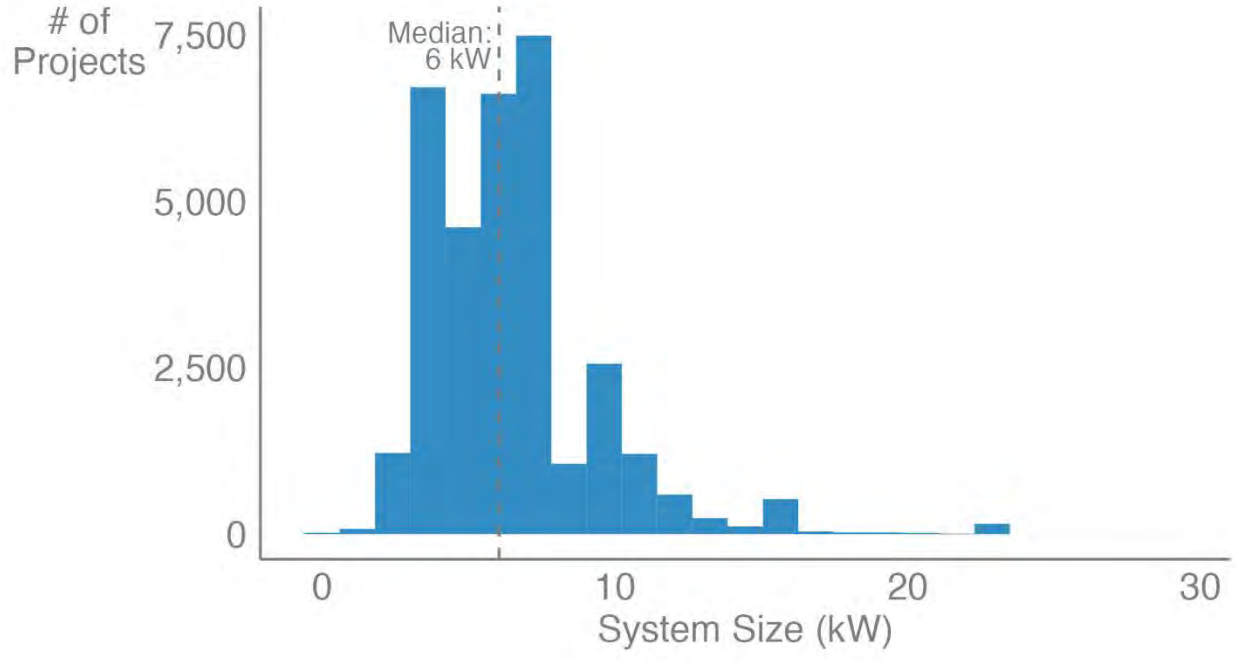


Figure 22. SolarAPP+ PV system size (kW) distribution for PV-only projects (N = 33,359)

A.2 Solar Modules and Inverters

Figure 23 depicts the distribution of module brands used in SolarAPP+ PV-only projects. Module brands largely reflect installer preferences and contractual agreements with module manufacturers. Data from EnergySage (2024) show that Hanwha Q CELLS, Silfab, and

[13] As noted, the statistics in this section are based on cumulative data. However, the median system size restricted to permits submitted in 2023 is also about 6 kW, which is why we use that system size as the basis for our assumptions in Section 4.

Renewable Energy Corporation (REC) modules are similarly popular among other installers off the SolarAPP+ platform. In the PV+storage pilot, JA Solar, Hanwha Q CELLS, and Tesla account for about 77% of PV modules.

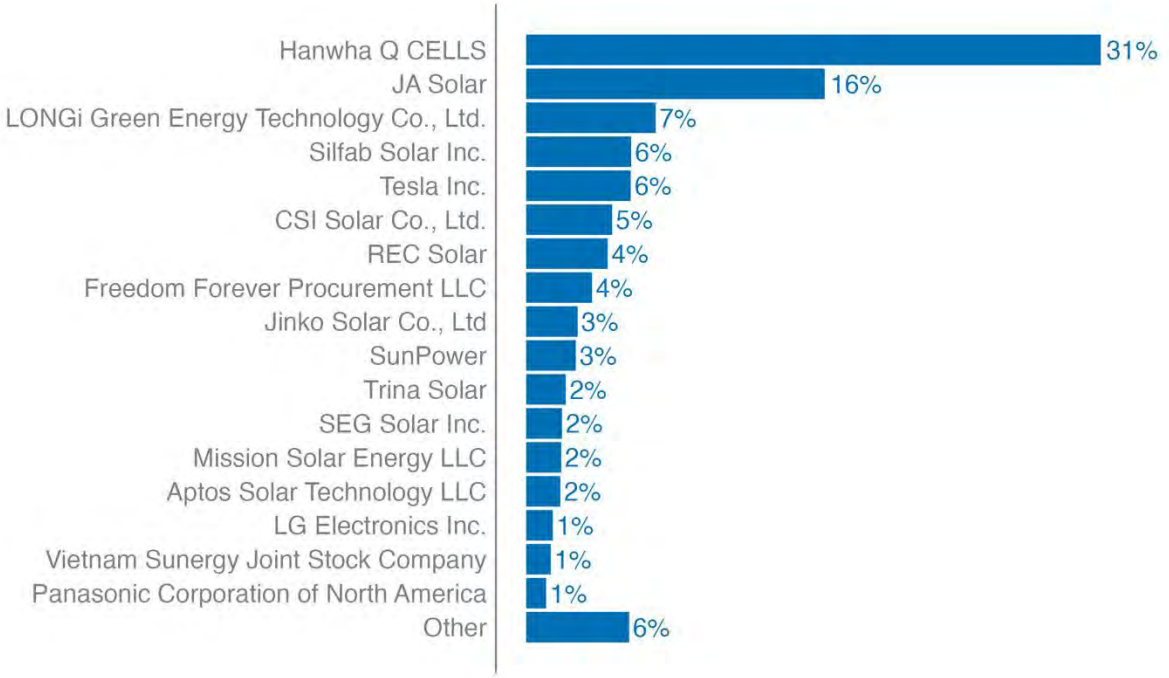


Figure 23. Module brand shares in SolarAPP+ PV-only projects (N = 33,363)

About 82% of SolarAPP+ PV-only systems include module-level power electronics, specifically DC optimizers (46%) and microinverters (36%) (Figure 24). That share is slightly less than the estimated residential marketwide share of 93% (Barbose et al. 2023). Module-level power electronics are less commonly reported in the PV+storage pilot, though the reasons for this remain unclear.

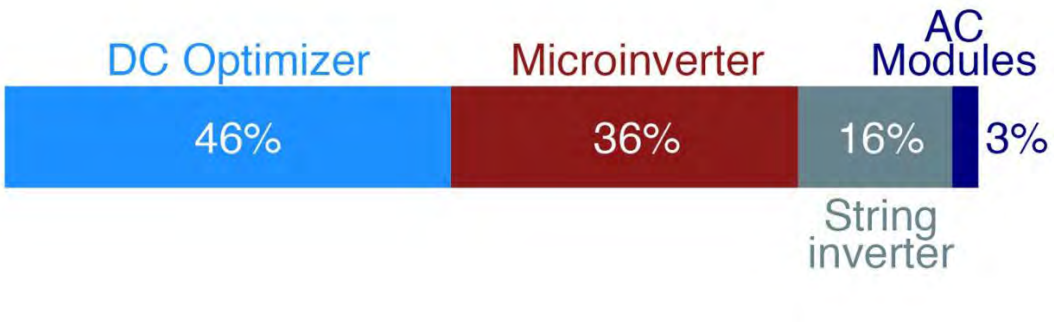


Figure 24. Inverter characteristics of SolarAPP+ PV-only systems (N = 33,363)

Note that percentages don't sum perfectly to 100 due to rounding.

Figure 25 depicts the distribution of inverter brands used in SolarAPP+ projects. Around 80% of SolarAPP+ projects use SolarEdge or Enphase brand inverters, similar to the share of those brands in the broader solar market as estimated by EnergySage (2024).

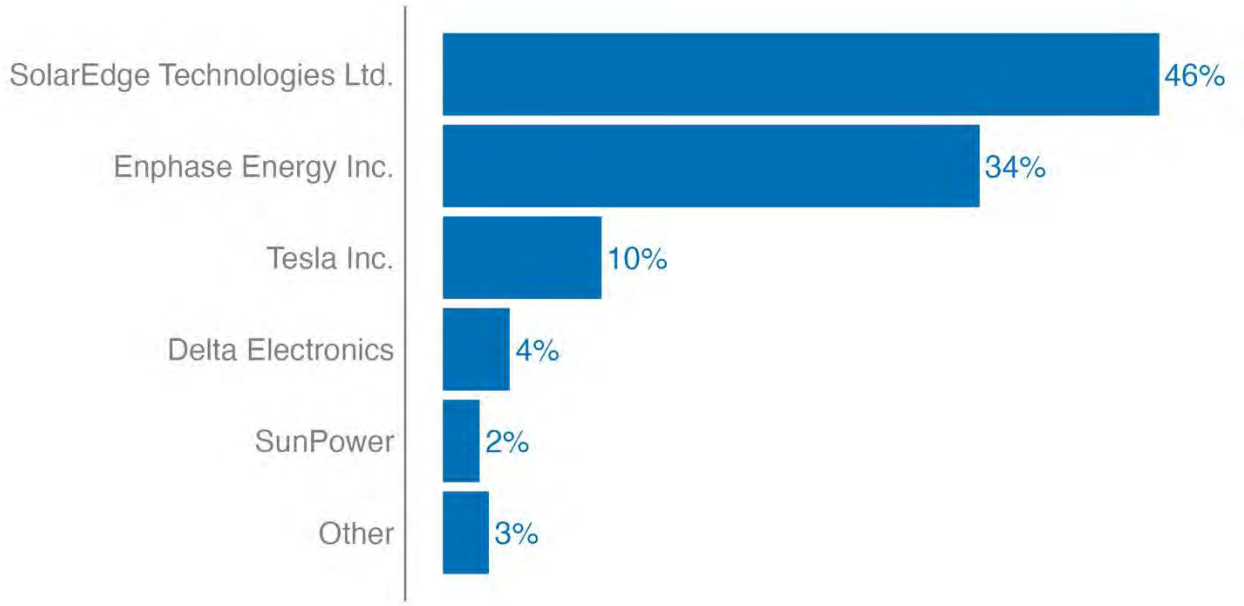


Figure 25. Inverter brand shares in SolarAPP+ PV-only projects (N = 33,363)

A.3 Home Electrical Upgrades and Interconnection Methods

Residential PV system installations can require upgrades to home electrical systems in certain cases. About 18% of SolarAPP+ PV-only permits and 10% of PV+storage permits were associated with a main panel upgrade (Figure 26). Further, about 12% of PV-only permits and 7% of PV+storage permits were associated with derating (reducing) the power limits of the home's main breaker, required in cases where the PV system could cause the home to exceed amperage limits set by the local utility. All PV systems require setting an amperage limit above which the system is automatically disconnected from the grid. SolarAPP+ service disconnect limits ranged from 100 or fewer amps (17% of systems) to 125 amps (5%), 150 amps (3%), 175 amps (8%), or 200 amps (67%). Finally, most SolarAPP+ PV-only systems are connected to the grid using the 120% rule, meaning that the installed system amperage cannot exceed the home meter's safety limit by more than 20%. In contrast, the most common interconnection rule in the PV+storage pilot is the sum-of-breakers rule, which requires that the sum of the home's load and electrical supply (i.e., from PV and batteries) does not exceed the rated capacity of the busbar connecting the home to the distribution grid.

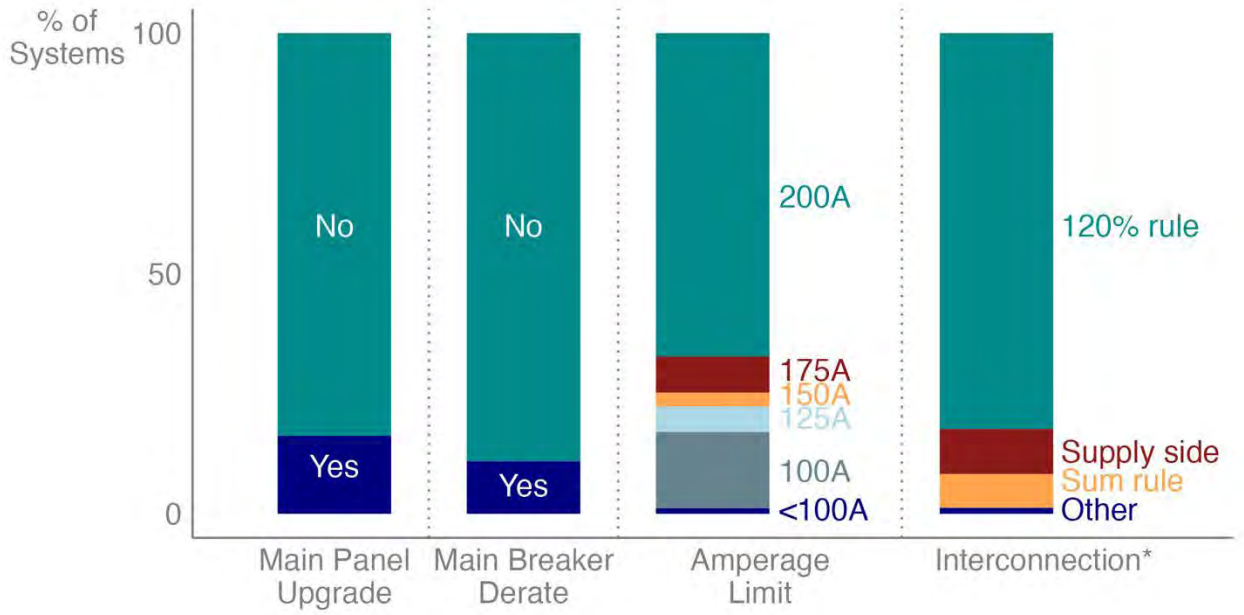


Figure 26. Electrical upgrade features of SolarAPP+ systems

Sample sizes: Panel upgrade N = 25,890; breaker derate N = 19,922; amperage limit and interconnection N = 14,335. *Sum rule = sum of breaker rule; supply-side = supply-side connection; “Other” includes 120% rule on center-fed panels, power control system, and 100% rule

A.4 Battery Characteristics

The following four figures depict data on battery system characteristics. Note that each figure is based on a subsample of data with available information. In some cases, missing data may skew the distributions. For instance, Figure 27 depicts the distribution of battery manufacturers for 569 systems with available data. This distribution is substantially different from other reported distributions (e.g., EnergySage 2024), either because of data reporting issues or because installers that use SolarAPP+ prefer different manufacturers.

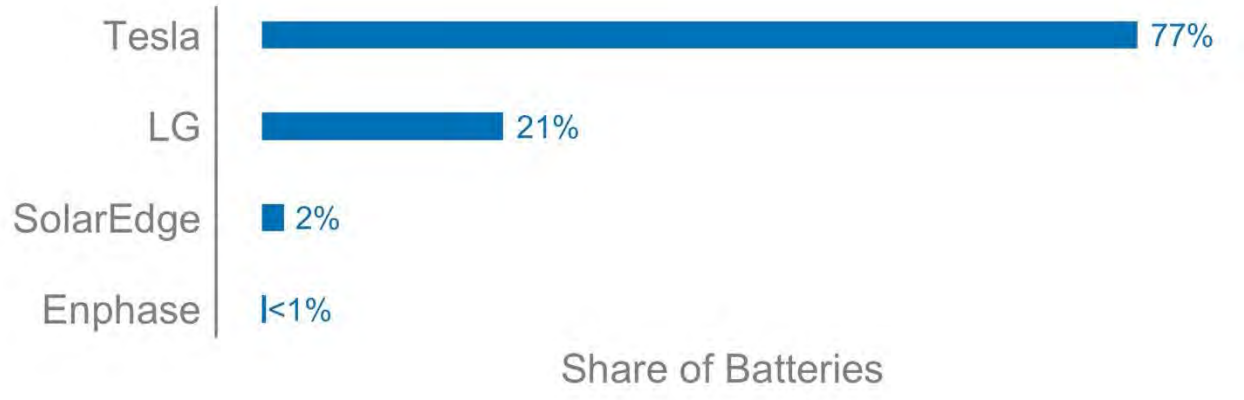


Figure 27. Distribution of battery manufacturers (N = 569)

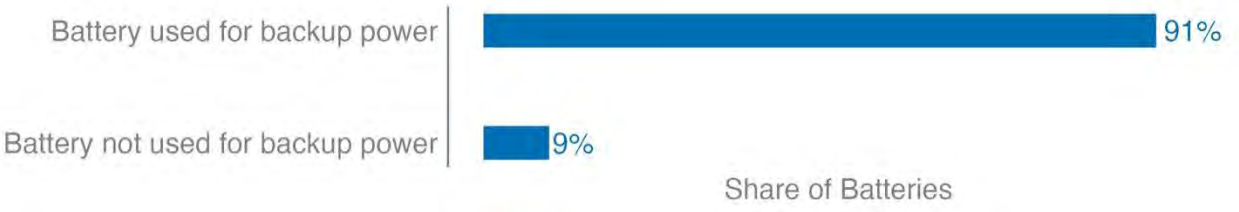


Figure 28. Distribution of batteries used for backup power (N = 945)

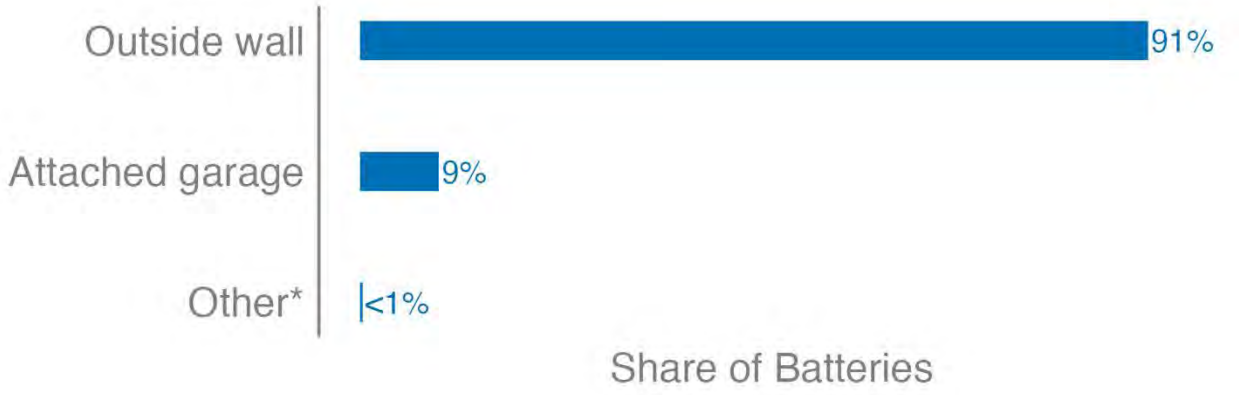


Figure 29. Distribution of battery storage mount locations (N = 5,548)

* Includes accessory structures, basements, detached garages, storage units, and utility spaces

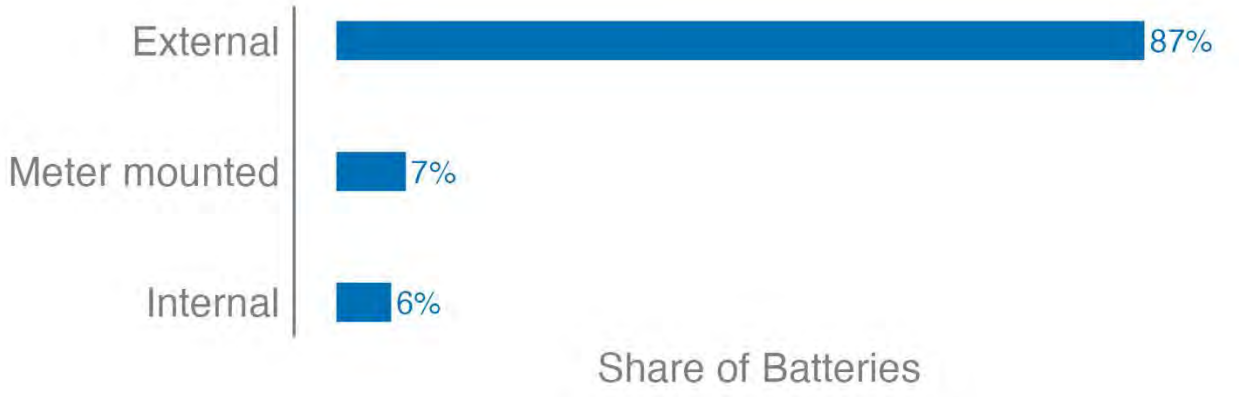


Figure 30. Distribution of battery storage initiation device locations (N = 1,140)

Cost-Reduction Roadmap for Residential Solar Photovoltaics (PV), 2017–2030

Kristen Ardani, Jeffrey J. Cook, Ran Fu, and Robert Margolis
National Renewable Energy Laboratory

Technical Report
NREL/TP-6A20-70748
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List of Acronyms and Abbreviations

¢/kWh	Cents per kilowatt-hour
($/Wdc)	Dollars per watt direct current
AHJ	Authority having jurisdiction
ASP	Average selling price
ATB	Annual Technology Baseline
BOS	Balance of system
DOE	U.S. Department of Energy
EIA	U.S. Energy Information Administration
EPC	Engineering, procurement, and construction
GW	Gigawatts
LCOE	Levelized cost of energy
kW	Kilowatts
NREL	National Renewable Energy Laboratory
O&M	Operations and maintenance
PII	Permitting, inspection, and interconnection
PV	Photovoltaic(s)
Q1	Quarter one
RECS	Residential Energy Consumption Survey
SETO	Solar Energies Technologies Office
USD	U.S. dollars

Executive Summary

The installed cost of solar photovoltaics (PV) has fallen rapidly in recent years and is expected to continue declining in the future. In this report, we focus on the potential for continued PV cost reductions in the residential market. From 2010 to 2017, the levelized cost of energy (LCOE) for residential PV declined from 52 cents per kilowatt-hour (¢/kWh) to 15.1 ¢/kWh (Fu et al. 2017). The U.S. Department of Energy's (DOE's) Solar Energy Technologies Office (SETO) recently set new LCOE targets for 2030, including a target of 5 ¢/kWh for residential PV. We present a roadmap for achieving the SETO 2030 residential PV target.

Because the 2030 target likely will not be achieved under business-as-usual trends (NREL 2017), we examine two key market segments that demonstrate significant opportunities for cost savings and market growth: installing PV at the time of roof replacement and installing PV as part of the new home construction process. We estimate that, between 2017 and 2030, an average of 3.3 million homes per year will be built or require roof replacement. This translates into a residential PV technical potential of roughly 30 gigawatts (GW) per year (Figure ES-1). Capturing even a relatively small fraction of this technical potential could have a significant impact on the evolution of the U.S. electricity system.

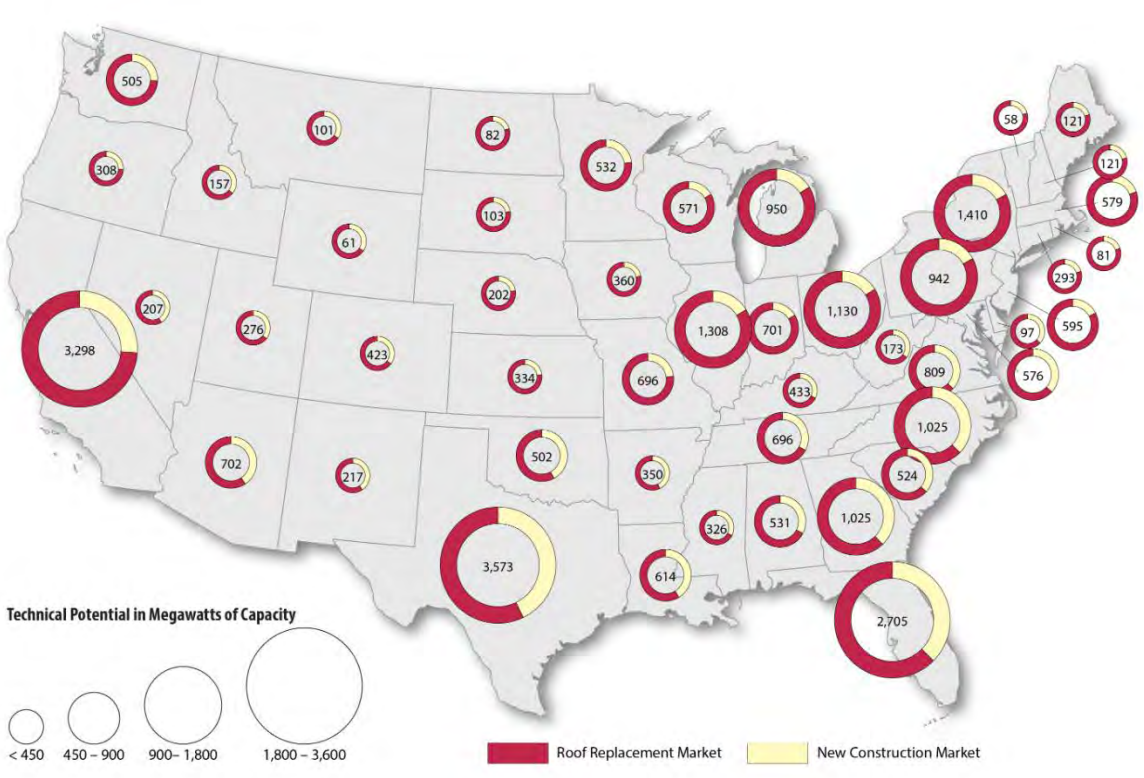


Figure ES-1. Annual average technical potential for residential rooftop PV at time of roof replacement and new construction projected between 2017 and 2030

Within both market segments, we identify four key cost-reduction opportunities: market maturation, business model integration, product innovation, and economies of scale. To assess the potential impact of these cost reductions, we compare modeled residential PV system prices in 2030 to the National Renewable Energy Laboratory's (NREL's) quarter one 2017 (Q1 2017)

residential PV system price benchmark (Fu et al. 2017). We use a bottom-up accounting framework to model all component and project-development costs incurred when installing a PV system. The result is a granular accounting for 11 direct and indirect costs associated with installing a residential PV system in 2030.

It is unlikely that all PV installers in these two market segments will pursue the same cost-reduction strategies, so we model four pathways that could be pursued to achieve low-cost residential PV in 2030 (Table ES-1). The two less-aggressive pathways represent a more conservative shift from current technologies and business practices, whereas the two visionary pathways represent a higher level of innovation. We assume that market maturation and subsequent supply chain efficiencies will yield cost reductions across all four modeled pathways by 2030.

Table ES-1. Four Modeled Pathways by Market and Magnitude of Cost Reductions

	Pathway			
	Roof Replacement Market		New Construction Market	
Cost-Reduction Opportunity	Less Aggressive	Visionary	Less Aggressive	Visionary
Market Maturation	High	High	High	High
Business Model Integration	Low	High	Low	High
Product Innovation	Low	High	Low	High
Economies of Scale	NA	NA	Low	High

All four modeled pathways demonstrate significant installed-system price savings over the Q1 2017 benchmark, with the visionary pathways yielding the greatest price benefits (Figure ES-2). The largest modeled cost savings are in the supply chain, sales and marketing, overhead, and installation labor cost categories.

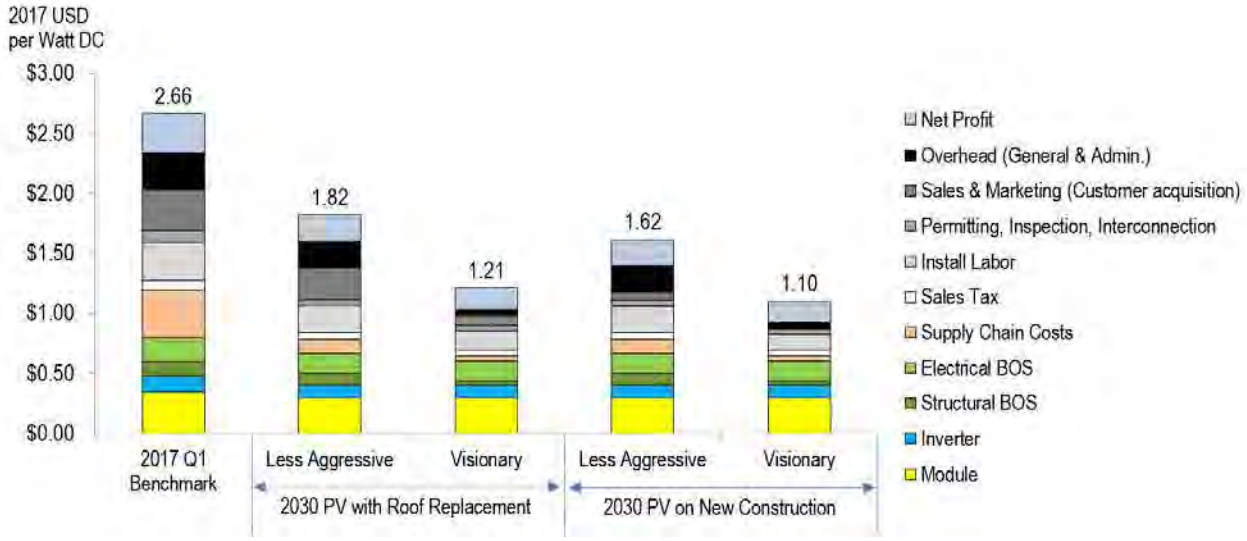


Figure ES-2. Modeled installed residential PV system prices at time of roof replacement and new construction in 2030, compared with a weighted average of the Q1 2017 benchmark

When we translate these installed-system costs into LCOE, we find that the less-aggressive pathways achieve significant cost reductions, but may not achieve the 2030 LCOE target (Figure ES-3). On the other hand, both visionary pathways could result in PV system prices that get very close to (for roof replacement) or achieve (for new construction) the 2030 target in each market segment.

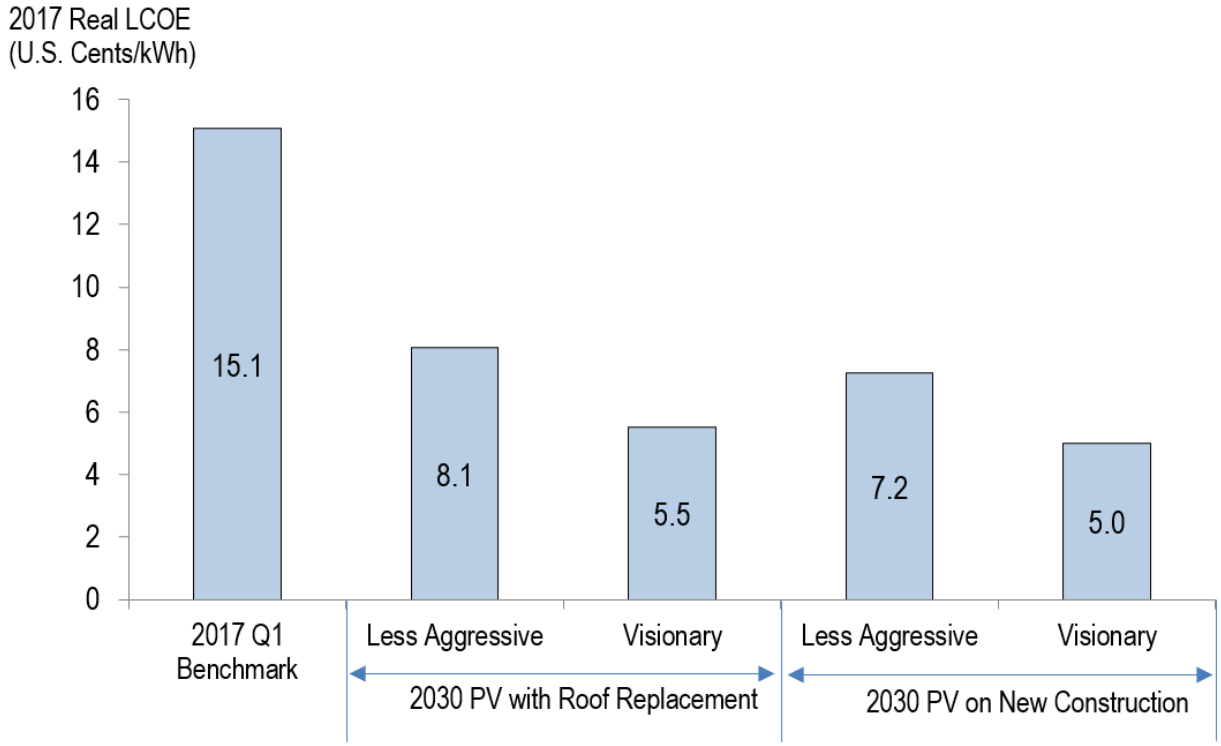


Figure ES-3. Modeled residential PV LCOE at time of roof replacement and new construction in 2030, compared with the LCOE for a weighted average of the Q1 2017 benchmark

Figure ES-4 compares the LCOE impacts of our modeled installed-system cost reductions with the impacts of improvements in other parameters, for the new construction visionary pathway. The results indicate that savings associated with installed-system soft costs account for about 65% of the total savings. Therefore, reducing these soft costs likely will be critical for achieving the 2030 residential PV target.

Although we identify pathways toward the 2030 residential PV target, various barriers and considerations must be addressed to realize this future. First, all four pathways benefit from anticipated market maturation that could significantly reduce supply chain costs. This analysis assumes that PV installers can procure modules at or near spot market prices in 2030. This future is likely to require significant innovation in business models as well as the proliferation of efficient procurement processes.

Second, the two visionary pathways assume that a low-cost integrated PV and roofing product is available by 2030, which could significantly reduce supply chain, installation labor, and permitting costs. Although integrated PV products have been or are being developed, achieving low-cost residential PV with an integrated product is very challenging and will likely require significant investments in research and development.

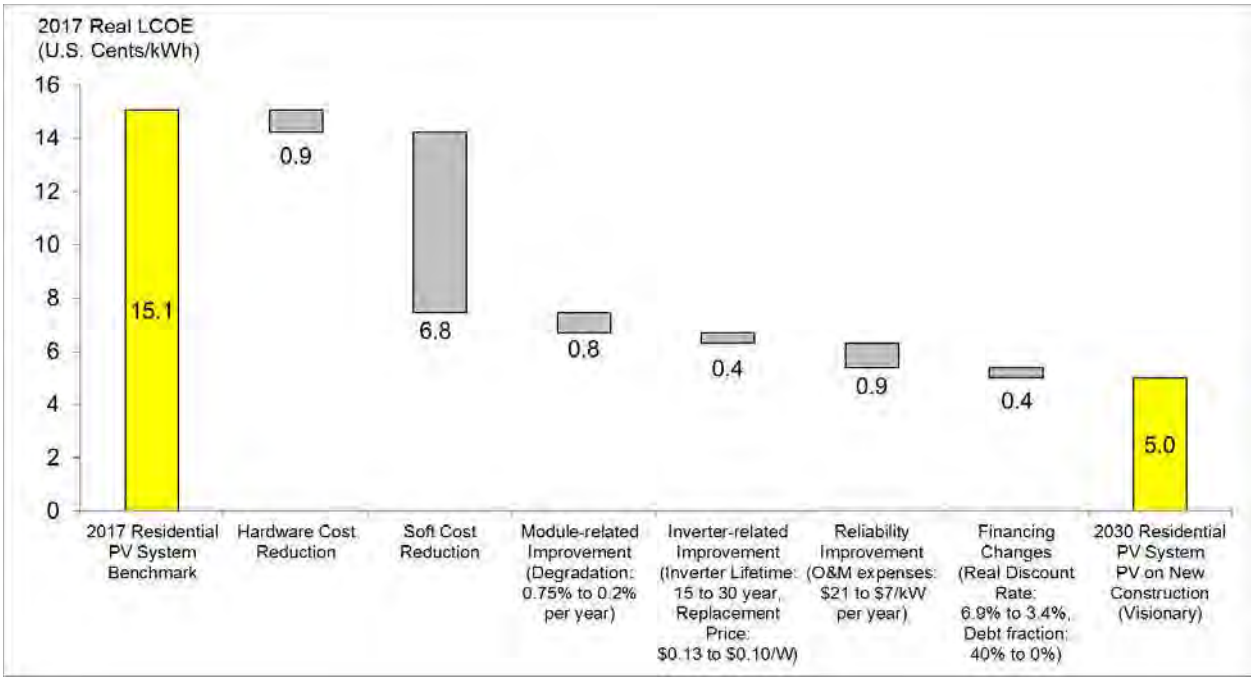


Figure ES-4. Modeled residential PV LCOE reductions for the new home construction market visionary pathway in 2030, compared with the Q1 2017 benchmark

Third, business model integration could provide significant sales, marketing, overhead, and labor savings that reduce installed PV system prices. Although there have been efforts to collaborate across the solar and roofing industries—and across the solar and housing industries—fully integrating across these types of businesses will require significant changes to existing practices. In addition, regulatory challenges such as variation in PV permitting requirements across more than 18,000 authorities having jurisdiction across the United States could serve as another barrier to increasing business model integration.

Fourth, economies of scale yield considerable cost savings, especially for the new construction market. However, the benefits of scale may be less than those assumed in our analysis, resulting from construction timelines, project sizes, and workforce management. In addition, those homebuilders that construct comparatively few homes (e.g., 20 or fewer homes annually), are unlikely to experience the same process efficiencies as those that construct hundreds of homes. In addition, potential permitting challenges and delays associated with deploying PV on new homes could result in additional costs that offset the savings benefits of economies of scale.

Overall, the results of our analysis suggest that it will be challenging but possible to achieve the SETO 2030 residential PV target. We identify two pathways that could play a transformative role in the residential PV sector: one by installing PV at the time of roof replacement, and the other by installing PV as part of the new home construction process. Achieving the SETO target via either pathway will require very aggressive reductions in hardware and soft costs driven by the development of new technologies, services, and business practices.

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1 Introduction

In 2011, the U.S. Department of Energy launched the SunShot Initiative to reduce residential, commercial, and utility-scale photovoltaic (PV) costs by 75% between 2010 and 2020 (DOE 2016). For residential PV systems, this meant reducing the average levelized cost of energy (LCOE) from 52 cents per kilowatt-hour (¢/kWh) to 10 ¢/kWh in 2020 (in 2017 dollars).[1] In 2016, DOE set even more aggressive targets to be achieved by 2030, including a residential PV LCOE of 5 ¢/kWh. This report outlines potential pathways for achieving the 5 ¢/kWh residential PV target by 2030.

Achieving the SETO 2030 target will require significant cost reductions beyond a business-as-usual scenario. In 2017, the average residential PV LCOE in the United States reached 15.1 ¢/kWh (Fu et al. 2017). Based on projections in the "mid" case of the NREL's Annual Technology Baseline (ATB), residential PV would reach an LCOE of 9 ¢/kWh in 2030 (NREL 2017).[2] Thus an additional reduction of 4 ¢/kWh would be required to achieve the SETO 2030 target.

To envision feasible pathways to realizing this aggressive 2030 target, we focus on two particularly promising residential PV markets: installing PV at the time of roof replacement and installing PV as part of the new construction process. We provide detailed component-level cost and system-level price projections for residential PV in these markets in 2030 based on four specific and plausible cost-reduction opportunities: market maturation, business model integration, product innovation, and economies of scale. We then convert the system price projections into LCOE values and analyze the potential of our modeled pathways to achieve the SETO 2030 target, along with the barriers that must be overcome to do so.

The remainder of this report is structured as follows: Section 2 describes the residential market opportunities for PV at time of roof replacement and on new home construction from 2017–2030. Section 3 describes the cost-accounting method we use to assess cost-reduction opportunities. Section 4 discusses our modeled cost-reduction opportunities and pathways. Section 5 shows our results, including the installed-system cost and LCOE reductions enabled by each pathway. Section 6 describes potential barriers to achieving the projected cost-reduction opportunities, and Section 7 discusses conclusions, study limitations, and directions for future research. Appendix A contains our underlying assumptions used to calculate the market potential for residential PV. Appendix B provides additional data and assumptions used in our modeling.

[1] LCOE is calculated by summing the cost to build and operate a PV system over the system's assumed financial life and dividing that total cost by the estimated lifetime electricity generation, yielding a value in cents per kilowatt-hour (EIA 2017a).

[2] This estimate is based on the ATB's mid-level cost projection in 2030 for residential PV with a 16.1% capacity factor (NREL 2017).

2 Technical Potential for Residential PV at Time of Roof Replacement and New Home Construction

From 2010 through 2016, cumulative installed residential PV capacity in the United States increased from 0.6 GW to 8.3 GW (GTM and SEIA 2016). Gagnon et al. (2016) estimate the continental U.S. technical potential for residential PV at 731 GW.[3] Thus residential PV installed through 2016 accounted for about 1% of the technical potential, suggesting opportunities for large-scale expansion.

We focus on two key market segments that offer significant opportunities for reducing costs and expanding the residential PV market: installing PV at the time of roof replacement and installing PV as part of the new home construction process. In the roof replacement market—after accounting for solar suitability and rooftop-replacement schedules—we project that an average of 2.3 million single-family detached homes per year could install PV between 2017 and 2030 in the continental United States (for detailed analysis assumptions see Appendix A). Assuming an average installed-system size of 5 kilowatts (kW) (roughly the average for residential systems installed in 2016), this would represent a potential of 11.5 GW per year. Installing the maximum suitable system size on all these homes would yield a potential of 22 GW per year.

In the new home construction market—taking into account historical suitability and construction rates—we project that an average of one million new single-family homes per year could install PV between 2017 and 2030 across the continental United States.[4] Assuming an average installed-system size of 5 kW, this would represent a potential of 4.8 GW per year. Installing the maximum suitable system size on all these homes would yield a potential of 9.3 GW per year (see Appendix A).

Summing these two potential markets together yields an average market size of 3.3 million homes per year. At an average system size of 5 kW, this would represent a potential of 16.3 GW per year. Installing the maximum suitable system size would yield a potential of 31.4 GW per year (Figure 1). The five states with the largest combined potential are Texas, California, Florida, New York, and Illinois. Capturing even a relatively small fraction of this potential could have a significant impact on the evolution of the U.S. electricity system.

[3] Gagnon et al. (2016) estimate the national technical potential of rooftop PV at 1,118 GW, with residential buildings—defined as those with a footprint of less than 5,000 square feet—accounting for 731 GW.
[4] It is possible that all new homes could be designed to avoid shading and other suitability barriers, which would increase the potential for rooftop PV.

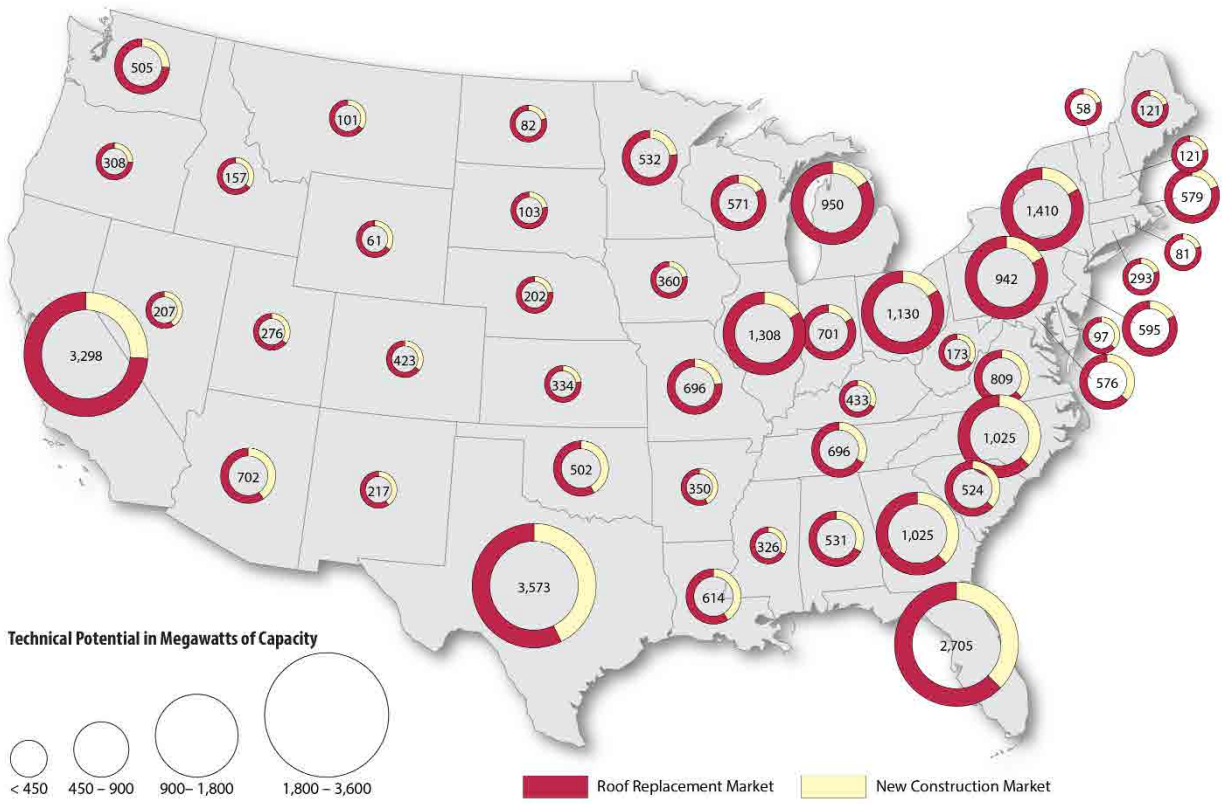


Figure 1. Annual average technical potential for residential rooftop PV at time of roof replacement and new construction projected between 2017 and 2030 (assuming the maximum suitable system size installed on all homes in these markets)

3 Methodology

To assess the potential impact of specific cost-reduction opportunities, we compare modeled residential PV system costs in 2030 to NREL's quarter one 2017 (Q1 2017) residential PV system price benchmark (Fu et al. 2017). Since 2010, NREL has benchmarked current PV system prices for the residential, commercial, and utility-scale sectors (Goodrich et al. 2012, Ardani et al. 2012, Chung et al. 2015, Fu et al. 2016, Fu et al. 2017). These benchmarks are generated using a bottom-up accounting framework for all component and project-development costs incurred when installing PV systems. The residential benchmark models the cash purchase price for systems excluding the federal investment tax credit.

All modeled costs represent the typical average selling price (ASP) between Tier 1 equipment suppliers and first buyers in the global market.[5] Generally, first buyers of equipment from the factory can be developers, engineering, procurement, and construction (EPC) contractors, installers, distributors, retailers, or other end users. Specifically, in our model, costs are represented from the perspective of the installer; thus all hardware benchmarks represent the ASP at which components are purchased by the installer. Importantly, we also apply a 17% fixed margin to all direct costs to model the sales price paid by the end user to the installer. This 17% fixed margin is referred to as "net profit" and is added to total installed costs as a separate category. Although we include assumptions for indirect costs such as business overhead, supply chain costs, and permitting costs, we do not include any additional end-user price gross-up, which is common in the marketplace. We use this approach owing to the wide variation in installer profits in the residential sector, where project pricing is highly dependent on region and project specifics such as local retail electricity rate structures, local rebate and incentive structures, competitive environment, and overall project or deal structures.

In general, the model captures typical installation techniques and business operations within a detailed bottom-up accounting framework. The result is a granular accounting for direct and indirect costs associated with installing a PV system. These cost categories include hardware costs, such as module and inverter prices, as well as "soft costs," such as costs related to the supply chain, labor, and sales and marketing (see Table 1).

For comparison to our 2030 modeled PV system prices, we use the benchmarked national weighted-average Q1 2017 system price for a retrofitted PV installation consisting of a 5.7kW system using 60-cell, multicrystalline, 16.2%-efficient modules from a Tier 1 supplier and a standard flush mount, pitched-roof racking system. The modeled costs of such a system, by category, are displayed in dollars per watt direct current ($/Wdc) in Table 1. In the Q1 2017 benchmark, the highest costs are related to the supply chain, modules, and sales and marketing.

[5] A Tier 1 supplier refers to an established company with its own branded solar panels and at least six projects with non-recourse financing from six different institutions. For more information on these firms, see BNEF (2017).

Table 1. National Weighted-Average Q1 2017 System Cost Benchmark for Residential Retrofit PV Installation by Cost Category (adapted from Fu et al. 2017)

Category	Modeled Value	Description
Module price	$0.35/Wdc	Ex-factory gate (first buyer) price, Tier 1 modules
Inverter price	$0.13/Wdc	Single-phase string inverter, ex-factory gate (first buyer) prices, Tier 1 inverter
Structural balance of system (BOS)	$0.11/Wdc	Includes racking and flashing for roof penetrations
Electrical BOS	$0.20/Wdc	Conductors, switches, combiners, and transition boxes, as well as conduit, grounding equipment, monitoring system or production meters, fuses, and breakers
Supply chain costs	$0.39/Wdc	Includes shipping and handling of equipment, historical inventory and small-scale procurement expenses for both modules and inverters
Sales tax	$0.08/Wdc	Sales tax on the equipment; national benchmark applies an average (by state) weighted by 2016 installed capacities
Direct installation labor	$0.32/Wdc	Modeled labor rate uses weighted average of state rates
Permitting, inspection, and interconnection (PII)	$0.10/Wdc	Includes assumed building permitting and interconnection application fees of $400 and six office staff hours for building permit preparation and submission, and interconnection application preparation and submission
Sales and marketing (customer acquisition)	$0.34/Wdc	Total cost of sales and marketing activities over the last year—including system engineering, marketing and advertising, sales calls, site visits, bid preparation, and contract negotiation; adjusted based on state “cost of doing business” index
Overhead (general and administrative)	$0.31/Wdc	General and administrative expenses—including fixed overhead expenses covering payroll (excluding permitting payroll), facilities, administrative, finance, legal, information technology, and other corporate functions as well as office expenses; adjusted based on state “cost of doing business” index
Profit	$0.32/Wdc	Applies a fixed 17% margin to all direct costs including hardware, installation labor, direct sales and marketing, design, installation, and permitting fees

We use the same cost-accounting framework to model residential PV system costs in 2030 for the roof replacement and new construction markets. Section 4 describes our specific cost-reduction opportunities and pathways.

Consistent with previous benchmarking efforts (Goodrich et al. 2012, Ardani et al. 2012, Chung et al. 2015, Fu et al. 2016, Ardani et al. 2017, Fu et al. 2017), we derived inputs for our model and validated our draft results via interviews with industry and other subject-matter experts. We interviewed 16 representatives from 13 leading organizations closely involved with PV product development and installation, roofing, and new home construction, including PV manufacturers,

PV and roofing installation companies, project developers, and industry associations. In these interviews, we focused on gaining a deeper understanding of future trends related to PV product integration, new business models that enhance collaboration across the PV, roofing, and new construction industries, deployment challenges, future cost-reduction opportunities, and cost-model refinement and validation. Our results highlight common themes from interviews. Finally, we also gathered information and data through a review of the published literature.

4 Pathways to Low-Cost Residential PV

The residential PV market is likely to evolve substantially between 2017 and 2030. Although the system cost reductions required to achieve the SETO 2030 target may seem very challenging today, we identify pathways to this goal that are plausible if significant and sustained technology and business-model innovations are realized. We model a total of four pathways, which are characterized by market (roof replacement vs. new construction) and magnitude of cost reductions achieved via four specific cost-reduction opportunities. Section 4.1 describes the cost-reduction opportunities, and Section 4.2 describes the pathways.

4.1 Key Plausible Cost-Reduction Opportunities through 2030

Although there are various opportunities to reduce residential PV costs through 2030, we identify four key opportunities—market maturation, business model integration, product innovation, and economies of scale—and their potential impacts on PV system cost categories.

4.1.1 Market Maturation

Since 2014, the top five residential PV installers captured between 39%–57% of the U.S. market on a quarterly basis (Shiao et al. 2017). The remaining market has been served by a wide array of midsize and small installers. In recent years, there has also been a rapidly evolving set of back office support, software, and other types of firms that serve midsize and small installers. Today, high-volume installers typically have the purchasing power to negotiate lower module and component prices compared with lower-volume installers, especially when bulk purchasing modules and other components from suppliers. With increased PV market maturation, these pricing differentials could be significantly reduced through the development of a mature supply chain, distribution channels, and support services aimed at small, medium, and large companies. Our analysis assumes that, between 2017 and 2030, the market matures such that small, medium, and large installers can procure modules and other components at or near the spot market prices modeled in Woodhouse et al. (2016). This significantly reduces supply chain costs.

4.1.2 Business Model Integration

Currently, most solar companies operate independently from roofing companies and homebuilders, and they often do not coordinate with these traditionally separate businesses. However, some solar companies have begun to collaborate with roofing companies and/or homebuilders to offer PV to prospective customers. For example, SunPower, a PV manufacturer and installer, currently partners with 10 of the 13 largest homebuilders in California to deploy PV on new construction (SunPower 2017). In addition, some roofing companies have begun to integrate PV into their product offerings and businesses more broadly (Solar Power World 2017). Business model integration is less common in the housing industry, but this market segment is quickly evolving. For example, Lennar—the second-largest U.S. housing company—deploys PV on its new homes via its subsidiary SunStreet (Professional Builder 2016, Lennar 2017).

Increased business model integration can offer cost savings over a PV-only approach, including lower customer-acquisition costs, labor time, and overhead expenses. For example, PV can be integrated into existing sales and marketing programs from roofing and housing companies, with reduced added costs. Similarly, overhead expenses and installation labor costs could be reduced by eliminating duplicate back office expenses and integrating installation crews.

4.1.3 Product Innovation

Product innovation could take a variety of forms, such as reduced PV racking and mounting, preassembled PV, and low-cost PV roofing tiles. An integrated PV and roofing product, in particular, could yield significant cost savings, especially if the roof and PV system could be shipped and installed in unison. Although integrated products have low market share today, it is plausible that they could reach the mass market by 2030. For example, several companies have recently introduced or are developing integrated PV products (CertainTeed 2017, GAF 2017, Tesla 2017). Product innovation along these lines could influence the labor, supply chain, and structural BOS cost categories.

Our analysis is limited to standalone PV and does not examine product innovation related to PV plus storage. However, there is a growing interest among homeowners in bundled PV systems that include dispatchable load, batteries, and electric vehicles. Previous NREL analysis shows that bundled PV product offerings allow homeowners to increase PV self-consumption and realize greater value from PV generation by temporally shifting customer load under the PV production curve (O'Shaughnessy et al. 2017). Given the cost declines and the potential benefits of PV plus storage solutions, by 2030 solar homebuilders and roofing companies are likely to expand their offerings beyond standalone PV systems to include storage as well. Early signs of this trend can be seen in the United States, with limited examples of battery manufacturers announcing partnerships with homebuilders to install batteries alongside PV on new construction (Tech Home Builder 2017).

4.1.4 Economies of Scale

Economies of scale are likely to be most accessible to the new housing market, because the cost of individual systems could be reduced by spreading fixed costs across multiple installations. Homebuilders often construct an entire subdivision (averaging 60 housing units), so a combined, or closely related homebuilder/PV installer could achieve cost savings by installing multiple PV systems simultaneously.[6] For example, combining installations could reduce labor costs by requiring the work crew to go to a subdivision only once to complete multiple installations. The overall benefit of economies of scale varies by the quantity of PV systems installed in a particular area, but the key cost categories affected include labor, sales and marketing, and PII costs. Achieving economies of scale in the roof replacement market is more difficult because, with the exception of major storms, rarely does an entire neighborhood require roof replacement at the same time.

4.2 Modeled Cost-Reduction Pathways

Our four modeled pathways explore the impact the cost-reduction opportunities from Section 4.1 could have on residential PV system costs compared with the Q1 2017 benchmark. For each market (roof replacement and new construction), a less-aggressive pathway represents savings due to an incremental shift from current market practices, and a visionary pathway represents savings due to a more dramatic shift. Table 2 characterizes each of the four modeled pathways

[6] The average number of housing units in a subdivision is from a 2014 National Association of Home Builders survey (Emrath 2014).

by market and magnitude of cost reductions realized (i.e., low and high). The remainder of this section discusses the pathways in more detail.

Table 2. Four Modeled Pathways by Market and Magnitude of Cost Reductions

	Pathway			
	Roof Replacement Market		New Construction Market	
Cost-Reduction Opportunity	Less Aggressive	Visionary	Less Aggressive	Visionary
Market Maturation	High	High	High	High
Business Model Integration	Low	High	Low	High
Product Innovation	Low	High	Low	High
Economies of Scale	NA	NA	Low	High

4.2.1 Roof Replacement Market

In the roof replacement market, the less-aggressive pathway models a solar company that maintains its own separate business but loosely partners with a roofing company. These two separate companies may share business leads and office space, but they are not fully integrated into a single company. In addition, the solar company continues to install traditional racked and mounted rooftop PV. Finally, this pathway does not yield a benefit from economies of scale, because PV installed during roof replacement is typically on a project-by-project basis.

In contrast, the visionary pathway represents a company that realizes the available cost-reduction opportunities more fully. A completely integrated roofing and solar company incorporates a low-cost integrated PV and roofing product (a low-cost roofing tile or some other innovative product) into all roof offerings. As with the less-aggressive pathway, economies of scale provide no savings in this pathway.

4.2.2 New Construction Market

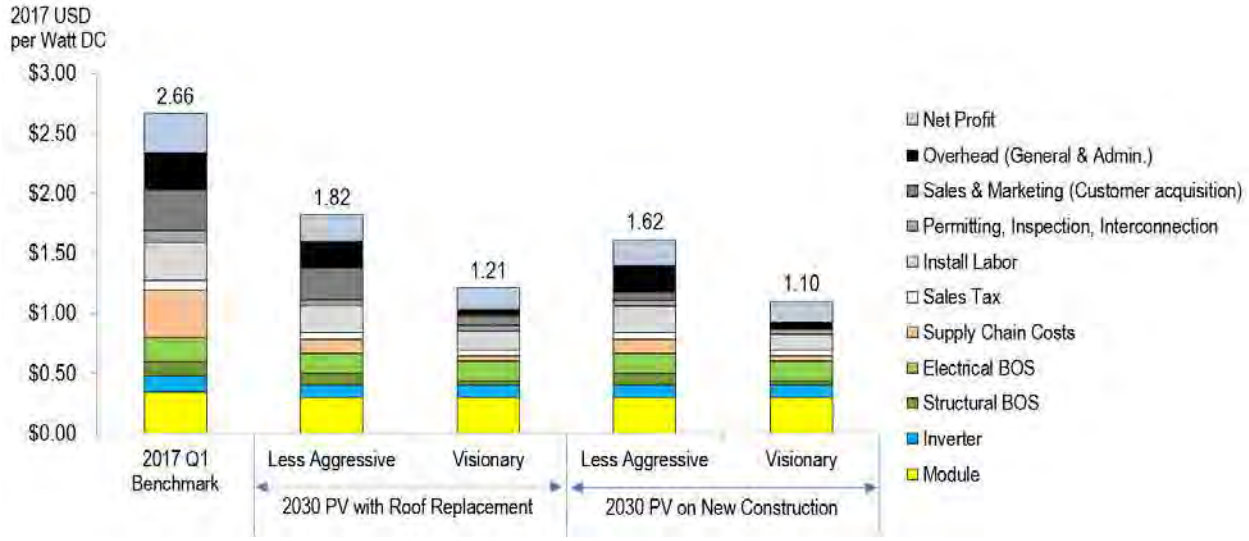
In the new construction market, the less-aggressive pathway is similar to its counterpart in the roof replacement market. The PV installer is only loosely affiliated with a homebuilder and may share office space with the homebuilder or roofing company (when the homebuilder subcontracts the roofing portion of new homes). The PV installer may also establish a formal partnership with a homebuilder, but it is not fully integrated into the construction process/business. The PV installer continues to install a traditional racked and mounted PV product and realizes some economies of scale; we assume the installer can leverage its partnerships with the housing industry to install PV on at least 25% of homes in a typical subdivision (i.e., 60 housing units, per Emrath 2014).

The visionary pathway, in contrast, assumes PV is fully integrated with the home design-build process from the start. It also assumes use of a low-cost integrated PV and roofing product as well as significant economies of scale due to installing PV on all new homes within a subdivision.

5 Cost-Reduction Results by Pathway

Figure 2 shows installed residential PV system prices for each of our modeled pathways in 2030, which all provide significant savings over the Q1 2017 benchmark (see Appendix B for detailed cost breakdowns and assumptions). Savings are largest in the supply chain, sales and marketing, overhead, and installation labor cost categories. Much of the supply chain savings result from the assumed market maturation that eliminates module price premiums related to historical inventory and small-scale procurement (potential savings of $0.27/Wdc); these savings are consistent across each of the pathways. The remaining three cost-reduction opportunities (business model integration, product innovation, and economies of scale) influence the PV system prices in each modeled pathway differently.

Because the two visionary pathways provide substantially larger cost savings compared with their less-aggressive counterparts, we present detailed cost-modeling results for these two pathways in Sections 5.1 and 5.2.



USD = U.S. dollars

Figure 2. Modeled installed residential PV system prices at time of roof replacement and new construction in 2030, compared with a weighted average of the Q1 2017 benchmark

5.1 Roof Replacement Market

The 2030 residential installed PV system price in our roof replacement visionary pathway is 55% lower than the Q1 2017 benchmark system price. Figure 3 breaks out the savings by cost category. The greatest savings are derived from the supply chain, sales and marketing, overhead, and installation labor categories.

Most supply chain efficiencies arise from market maturation (see Section 4.1.1). However, additional supply chain savings are realized under the visionary pathway relative to the less-aggressive pathway, because PV is integrated into the roofing material in the visionary pathway. This product integration would allow the PV and roofing material to be shipped together, thereby eliminating additional shipping costs. In contrast, the less-aggressive pathway assumes that companies continue to install traditional racked and mounted PV that is shipped and installed separately from the roof.

The full integration of a PV installer with a roofing company offers a significant sales and marketing benefit. Individuals invest in retrofitted PV systems voluntarily, but they typically replace their roofs owing to a specific requirement. Therefore, prospective customers may be more inclined to respond positively to PV marketing that is incorporated with a roof purchase, compared with the marketing of PV alone. At the same time, PV marketing could be integrated into existing roofing customer outreach, marketing, and advertising efforts at little or no additional cost. As a result, in the visionary pathway the fully integrated firm has a single sales and marketing budget to sell an integrated PV roofing product, which eliminates most customer acquisition costs (except for system design). In the less-aggressive pathway, we assume a solar company only loosely partners with a roofing company by, for example, sharing customer leads. In return for successful leads, the partner might receive a sales commission.[7] The savings achieved through this approach are substantially lower than the savings in the visionary case.

Similarly, fully integrating a PV installer with a roofing company yields significant overhead savings. A standalone solar company incurs typical overhead costs such as rent, office expenses, professional services, and software/information technology. Because the visionary pathway models an integrated solar and roofing business, these costs would be significantly reduced. Nevertheless, some additional costs would be associated with integration including acquiring PV or roofing expertise. In our model, we account for the costs of a roofing company acquiring PV expertise in the overhead category.

Installation labor costs are also reduced, owing to business model and product integration. Most conventional, racked and mounted rooftop PV systems can be installed by the same class of labor already employed by a roofing company,[8] and we assume that same labor class can be employed to install an integrated PV and roofing product. Combining roofing and PV installation activities creates synergies and logistic efficiencies that reduce truck rolls, crew-hours spent on site, and other direct transportation costs, such as fuel. The use of an integrated PV and roofing product in the visionary pathway also eliminates the labor required for racking and mounting installation, which provides additional labor cost savings over the less-aggressive pathway.

The roof replacement visionary pathway also benefits from savings in other cost categories. For example, the PII cost is reduced because we assume the PV permit cost declines to a standard $200 per system. Structural BOS savings are realized owing to the elimination of racking and mounting, in favor of the integrated product.

[7] Interview findings suggest a broad range of typical sales commissions, from $0.25/W to $1/W, in the current market, depending on the geographic region and pricing structure. For this analysis, we assume the commission is less than the cost of customer acquisition the solar company would otherwise incur working independently.
[8] Interviewees noted that, with appropriate training, many roofing installation crews today retain the level of expertise required to install the components of a PV system that are above the roof (e.g., racking, mounting, modules). However, most roofing companies would likely need to subcontract, or hire, an electrician to install PV system components such as electrical wiring and conduit.

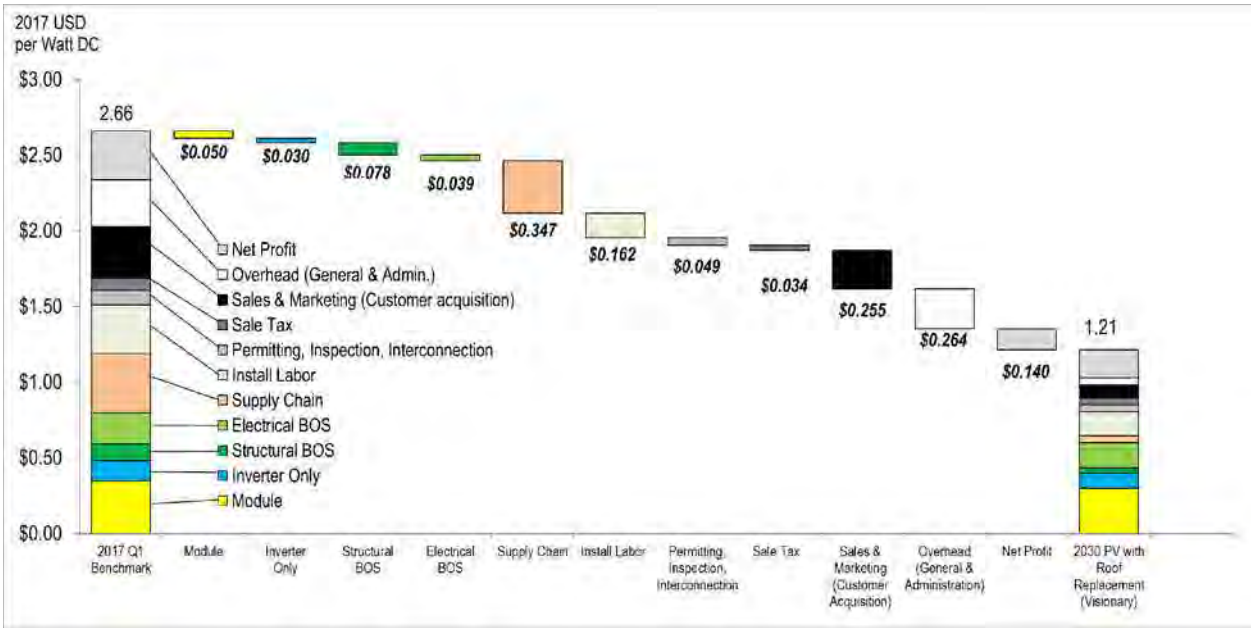


Figure 3. Cost reductions achieved by the roof replacement visionary pathway in 2030

5.2 New Construction Market

The 2030 residential installed PV system price in our new construction visionary pathway is 59% lower than the Q1 2017 benchmark system price (Figure 4), suggesting that installing PV on new homes could yield greater cost savings than installing it during roof replacement. The supply chain savings are the same for the two visionary pathways,[9] but the new construction visionary pathway achieves greater sales and marketing, installation labor, and PII savings, in part by leveraging economies of scale.

Sales and marketing costs are reduced in the new construction visionary pathway, because installing PV on every new home in a development eliminates customer acquisition costs that are currently typical for a retrofitted PV system, such as sales calls, site visits, customer outreach, and bid/pro-forma preparation. The roof replacement visionary pathway provides similar savings. However, installing PV on new homes provides additional savings via design and engineering standardization. Including standard PV system designs and sizes for each home floor plan reduces upfront engineering and design costs that would be incurred when completing a retrofitted PV installation of any kind.

Coordination and collaboration across construction and PV installation crews provides labor savings in both visionary pathways. However, the labor savings in the new construction pathway are greater, owing to economies of scale and the ability of PV installation crews to move readily across multiple co-located housing units.

PII savings are also greater in the new construction visionary pathway compared with the roof replacement visionary pathway, because integrating PV into the building permitting process

[9] Supply chain savings are the same in both visionary pathways because both pathways benefit from market maturation, as outlined in Section 4.1.1, and both incorporate installation of an integrated PV and roofing product.

required for the entire subdivision reduces PII costs per system. In addition, completing multiple new construction PV permits in succession results in savings associated with economies of scale.

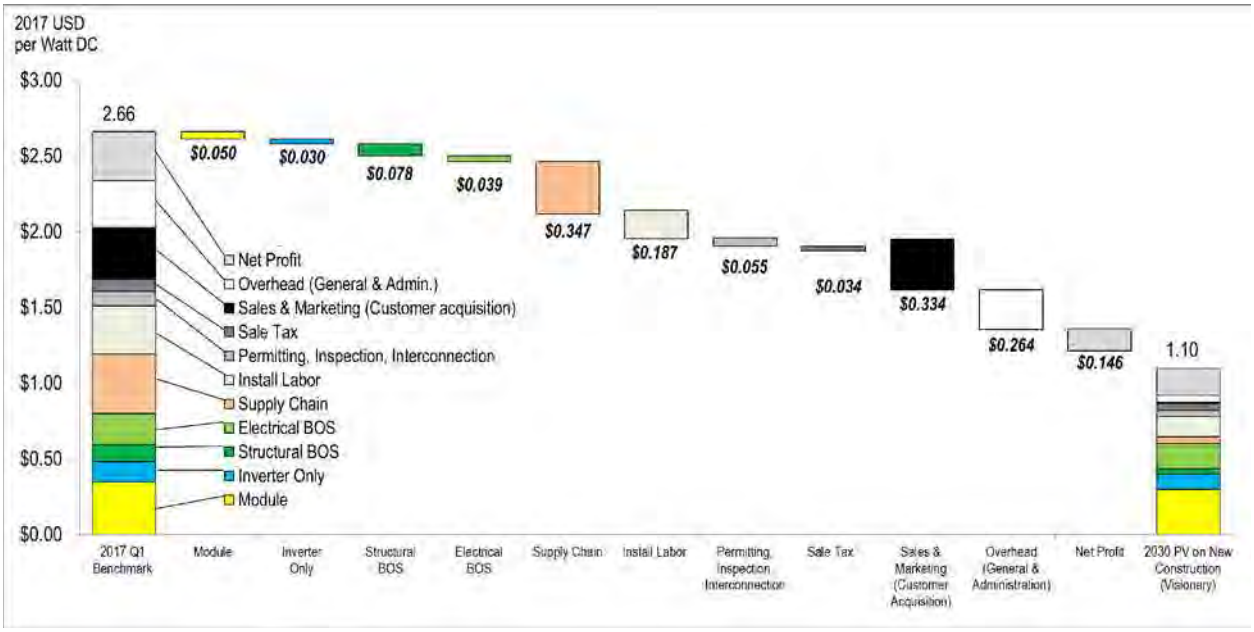


Figure 4. Cost reductions achieved by the new construction visionary pathway in 2030

5.3 Achieving the SETO 2030 LCOE Target

Installed-system prices are a key input for calculating residential PV's LCOE. Other parameters—such as lower operations and maintenance (O&M) costs, more favorable financing terms, and improved PV module performance—are also expected to contribute to declining LCOE through 2030 (Woodhouse et al. 2016). Here we combine our system price results with the other expected improvements to determine whether the SETO 2030 LCOE target can be achieved via our modeled pathways. We model an LCOE for the Q1 2017 benchmark based on the assumptions in Fu et al. (2017), and we model LCOEs for our four pathways based on our modeled system prices and key assumptions from Woodhouse et al. (2016) (Table 3).

As Figure 5 shows, the less-aggressive pathways could progress about 70%–80% toward the SETO 2030 LCOE target of 5 ¢/kWh. In contrast, the new construction visionary pathway achieves the target, and the roof replacement visionary pathway is slightly higher. Thus, our analysis suggests that moving toward a fully integrated roofing product and a fully integrated business model may be critical to achieving the SETO 2030 residential PV target.

Table 3. Assumptions for Calculating Residential PV LCOE

LCOE Cost Input (2017 USD/Wdc)	Q1 2017 Benchmark	2030 Pathways
Installed cost ($/W)	$2.66	Varies by pathway
Annual degradation (%)	0.75%	0.20%
Inverter replacement price ($/W)	$0.13	$0.10
Inverter lifetime (years)	15	30
O&M expenses ($/kw-year)	$21	$7
Pre-inverter derate (%)	90.50%	90.50%
Inverter efficiency (%)	98.00%	98.00%
System size (kWdc)	5.7	5.7
Inverter loading ratio	1.15	1.15
Real discount rate	6.9%	3.4%
Inflation rate	2.5%	2.5%
Debt interest rate	4.80%	4.80%
Debt fraction	40%	0%
Analysis period (years)	30	30

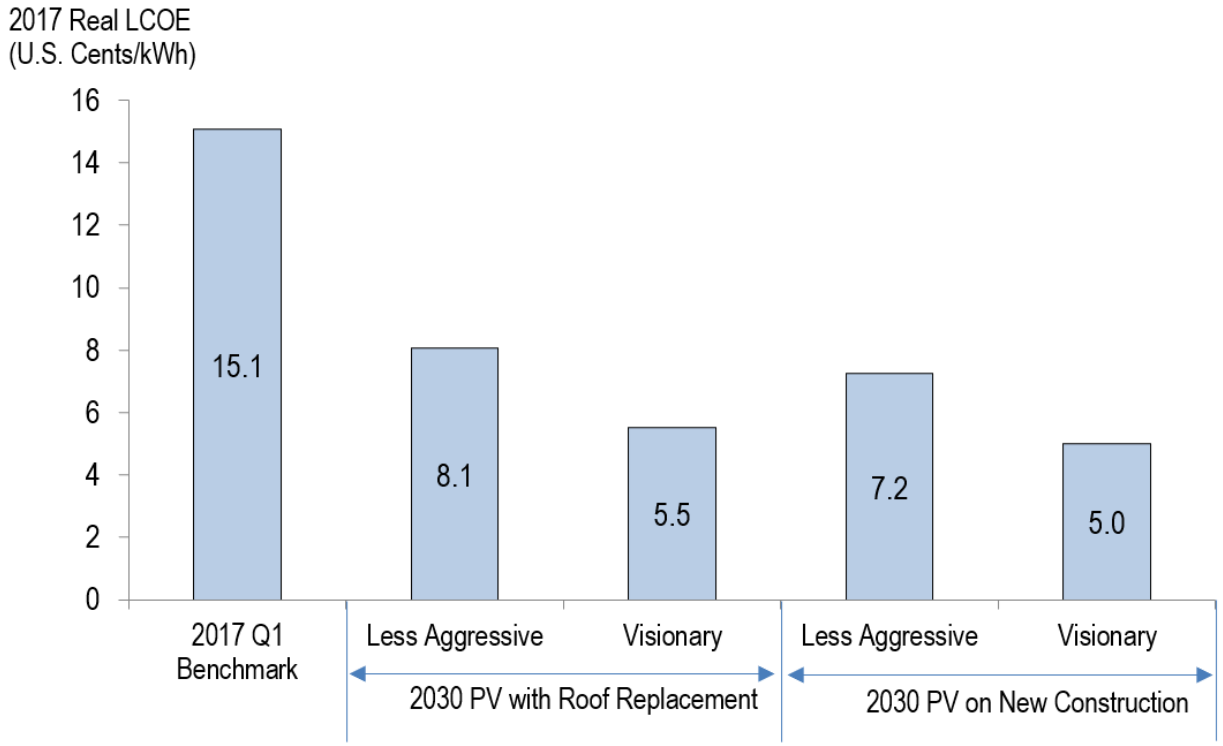


Figure 5. Modeled residential PV LCOE at time of roof replacement and new construction in 2030, compared with the LCOE for a weighted average of the Q1 2017 benchmark

In addition, reducing installed-system costs—particularly soft costs—likely will be critical to achieving the SETO 2030 target in either market. Figure 6 (roof replacement visionary pathway)

and Figure 7 (new construction visionary pathway) compare the LCOE impacts of installed-system cost reductions with the impacts of improvements in other parameters. In both pathways, installed-system soft cost reductions account for roughly 65% of the savings in 2030. None of the other individual parameters account for more than 9% of the LCOE reductions.

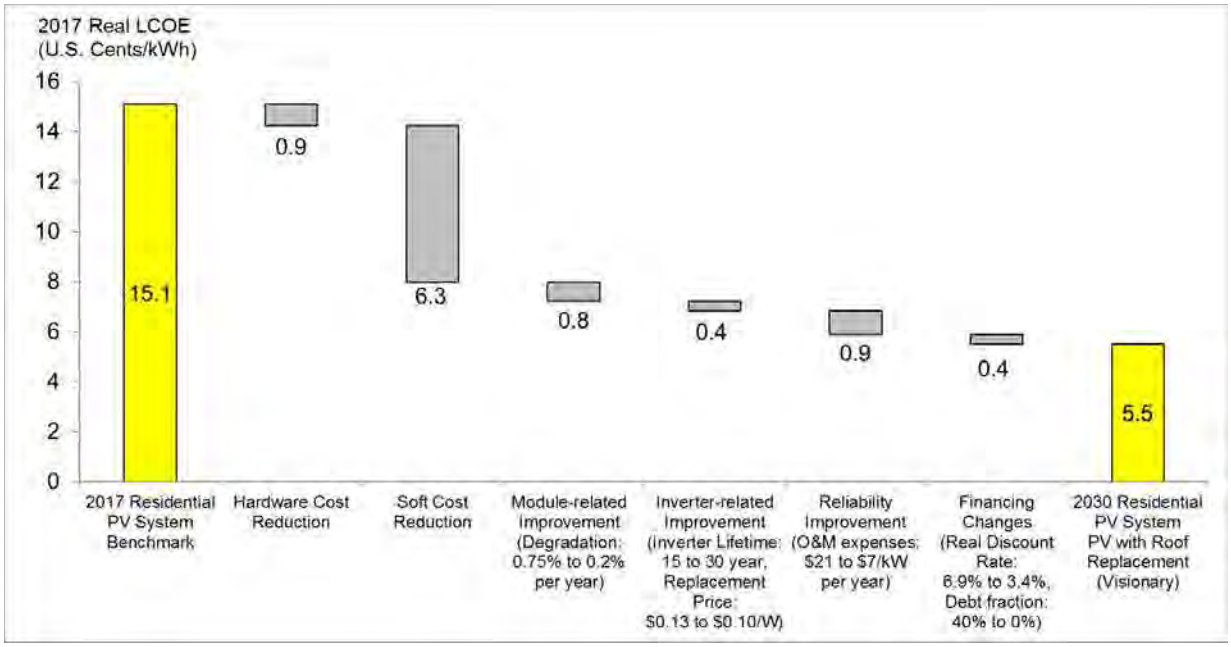


Figure 6. Modeled residential PV LCOE reductions for the roof replacement market visionary pathway in 2030, compared with the Q1 2017 benchmark

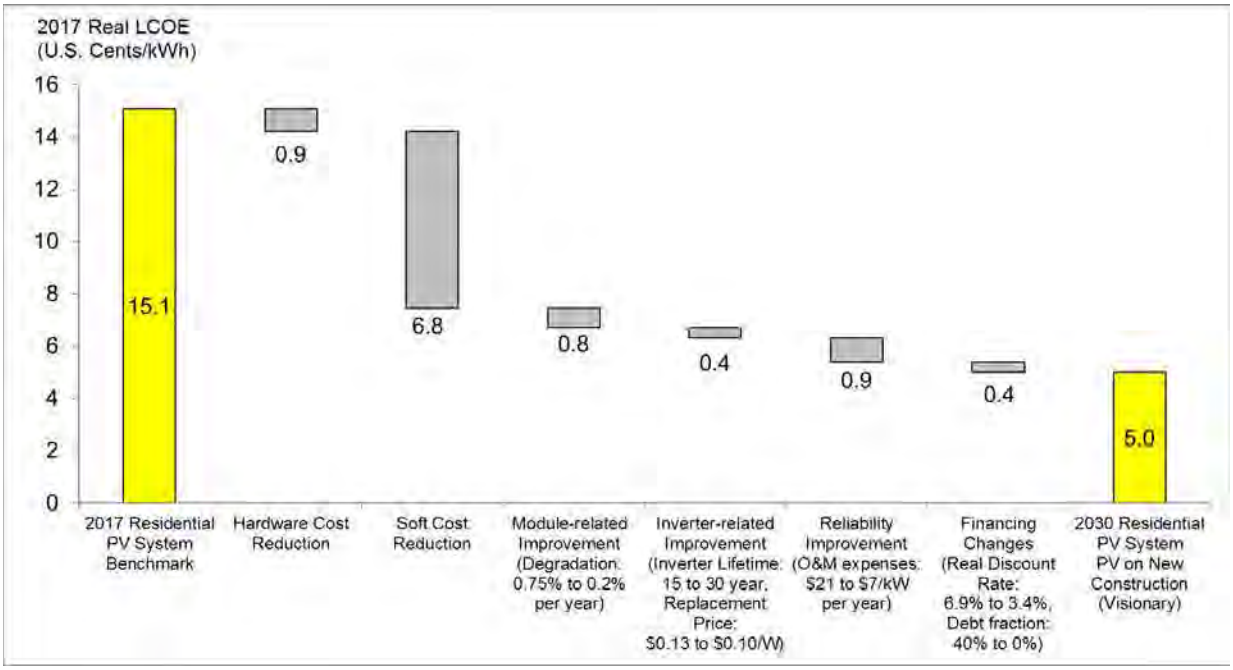


Figure 7. Modeled residential PV LCOE reductions for the new home construction market visionary pathway in 2030, compared with the Q1 2017 benchmark

6 Barriers and Considerations Related to Achieving the SETO 2030 Targets

Although we envision pathways toward ultra-low-cost residential PV in Section 5, our interviewees identified barriers and considerations that must be addressed to achieve these pathways. Here we examine these barriers and considerations in terms of the key cost-reduction opportunities. For two of these opportunities—market maturation and product innovation—the barriers and considerations are consistent across the roof replacement and new construction markets. For the other two opportunities—business model integration and economies of scale—barriers and considerations may differ between the markets.

6.1 Market Maturation

A significant portion of the supply chain cost reductions identified in our analysis is due to market maturation and a resulting narrowing of the gap between spot prices and wholesale prices. In part, this gap is an artifact of rapidly changing prices in a market with significant historical inventories and multiple transactions prior to the end user. As the U.S. PV market matures, we expect installers will be able to procure modules and other components more efficiently, thereby eliminating additional supply chain costs.

Interviewees suggested that the PV industry may reach maturity, as other commodity industries have, through a mix of consolidation and innovation in supply chain service. Some market consolidation is underway, and interviewees believed this trend will continue through 2030, particularly for equipment providers. At the same time, interviewees suggested the development of a diverse set of supply chain service providers that support PV installers will drive down procurement costs further, while increasing PV's value proposition. Interviewees pointed to existing service providers that partner with installers to reduce customer acquisition costs as a model for what is possible. In addition, various third-party service providers seeded by the DOE SETO Incubator Program (DOE 2017) already exist in the market.

If the PV industry reaches maturity, its practices could come to resemble those in other trades, with a robust installer market supported by more regional product dealer and service providers. However, realizing this future likely will require investment in developing new services and bringing them to market at sufficient scale to ensure profit and mass market appeal and to mitigate the procurement disadvantages of smaller purchasers. Currently, it is unclear whether the industry will mature enough to enable a wide variety of installers to procure modules at comparatively low markups. If the required maturation does not occur, the deep supply chain cost reductions we assume across all four pathways may not be achieved.

6.2 Product Innovation

Our two visionary pathways assume a low-cost integrated PV and roofing product is available by 2030, which would significantly reduce supply chain, installation labor, and permitting costs as the PV and roofing materials are shipped, installed, and permitted in unison. Whether integrated PV products can achieve lower costs and greater market share is uncertain at this time. If such a low-cost product does not materialize by 2030, our cost-reduction pathways would change.

Research and development of integrated PV products has been ongoing for years (James et al. 2011), and today there is renewed interest in integrated PV as new products come to market. Interviewees noted that early technology adopters are being drawn to new, integrated PV roofing materials at a price premium for the aesthetic value they provide. However, although many non-cost considerations affect the consumer decision-making process, integrated products must also be low-cost to appeal to a broad market.

Innovation will be required to develop low-cost integrated PV products. Interviewees noted that these custom products currently are produced on a smaller scale, require manufacturing process changes, and require more skill and time to install—all of which add costs. The lower efficiency of current integrated products also makes these products more expensive than conventional PV modules, because more integrated product is required to generate an equivalent amount of electricity. Robust design innovation that addresses these issues likely will be critical if integrated products are to capture significant market share through 2030.

6.3 Business Model Integration

Across both visionary pathways, business model integration is assumed to provide significant sales and marketing, overhead, labor, and PII cost savings that result in lower installed PV system prices. However, business model integration presents unique challenges for PV installed at the time of roof replacement and PV installed on new home construction.

6.3.1 Roof Replacement Market

Interviewees noted that the business models of solar and roofing companies are well aligned and that collaboration between these types of companies likely will increase. However, the need to have experienced solar sales professionals on staff can pose a barrier to roofing companies that want to sell PV directly to consumers. Several interviewees noted that the expertise required to sell PV effectively is significantly different from the expertise required to sell roofs. For example, solar sales professionals may be trained in residential utility rate structures and consumer load profiles, whereas roofers may not be trained in these areas. Therefore, roofing companies must train existing sales staff, or hire solar sales professionals, to sell PV and roofing products together effectively. At the same time, incorporating PV into a roof replacement may cost more than a roof replacement alone. Therefore, PV sales are not guaranteed, despite these investments.

Interviewees also suggested that improved PII processes are needed for solar-roofing companies to realize the full cost savings of business model integration. For example, under most authorities having jurisdiction (AHJs), a new roof and accompanying PV installation are treated as two individual projects for the purposes of permitting and inspection (even for integrated products). AHJs commonly require that, before commencement of PV installation, all permitting and inspection requirements for the new roof be completed, resulting in two distinct permitting packages and inspections. Combining the permitting and inspection processes for the new roof and PV installation would enable more timely and cost-efficient project completion. In addition, the lack of standardization in PV permitting, interconnection requirements, and fees across more than 18,000 AHJs and 3,000 utilities impedes installers' ability to deploy PV rapidly across numerous jurisdictions and utility territories (Grow Solar 2017, APPA 2017). Some states, including Vermont and Rhode Island, have adopted standardized PV permitting processes.

Others, such as New York and California, have directed AHJs to enact model standards. Despite this state-level progress, interviewees suggested that roofing companies may consider the lack of PV PII standardization as a financial risk, thereby deterring the expansion of product offerings to include PV.

6.3.2 New Construction Market

For solar companies that install PV on new housing developments, the target customer is the homebuilder, rather than the end user. This can result in significant sales and marketing savings over current business practices, because homebuilders likely will retain the same solar contractor across multiple developments. To date, most homebuilders do not incorporate PV into all new housing developments. Interviewees suggested that increased business model integration could be spurred by consumer interest, positing that, as homebuyers become familiar with PV's benefits, market demand for PV on new construction will increase. The effectiveness of this approach may be limited, however, because PV might compete with other home upgrades that provide higher revenue to homebuilders.

Interviewees suggested that favorable policy could enhance customer demand and foster more business model integration, highlighting various policy options that could achieve this goal. One common example was California's amended energy efficiency regulations under Title 24, which requires every new home be built to net-zero energy standards by 2020. Effective January 1, 2017, this amendment provided a compliance credit for PV that homebuilders can use to meet Title 24 net-zero energy requirements. Interviewees cited California's Title 24 amendment as a catalyst for PV on new construction, because PV can be more cost-effective than certain energy efficiency measures.

The presence of favorable policy alone, however, is unlikely to capture the full savings potential of business model integration. In California, when homebuilders incorporate PV into new construction as a Title 24 compliance measure, the PV can be included in the master building permit. Interviewees cited PII challenges with this approach. In this scenario, the master building permit serves as an umbrella permit for the entire house, so delays in PV PII can slow construction of the entire project. Similarly, changes made to the PV system design after the master building permit has been submitted would require revision and resubmittal of the entire permitting package. Interviewees suggested that allowing more flexibility for PV systems in the master building permit could address these concerns.

In addition, interviewees noted that solar partners often are not involved in the design of housing developments, which can impede the solar and new construction industries from realizing the full potential of collaboration. For example, when the PV installer is excluded from the housing development planning process, it has limited ability to co-optimize system design and roof layout, or take advantage of streamlined wiring and conduit with PV-ready housing designs. As PV becomes more common on new housing developments and consumers request maximum solar benefits, builders may be more inclined to consider solar exposure in building designs.

Finally, in the new construction market, PV engineers must design and size systems without the benefit of homeowner electricity-use data, which could result in standard system designs that are

smaller than would otherwise be installed for a residential retrofit.[10] These smaller system sizes may not maximize consumer benefits, but they may enable PV installers to meet strict building construction and permitting timelines. Interviewees suggested that the development and widespread use of software to model plug loads may help engineers size systems more effectively.[11] This and other innovations in the new construction market will likely be necessary to capture all of the cost savings associated with business model integration.

6.4 Economies of Scale

Although our pathways consider cost reductions associated with economies of scale only for the new construction market, the roof replacement market might see some benefits from this approach by 2030. For example, some interviewees suggested that a company could offer customers the option to defer a PV installation and roof replacement for several weeks at a reduced price to enable the pooling of customers in a particular area, thus maximizing the efficiency of crew logistics and truck rolls. However, many individuals requiring roof maintenance may not be able to wait for roof replacement, which limits this option.

In the new construction market, the modeled cost savings from economies of scale are highly uncertain. Alternative business models, construction timelines, project sizes, and workforce management may diminish or enhance our projected cost savings. Furthermore, company size can greatly influence a homebuilder's ability to maximize the benefits of economies of scale. For example, companies that construct fewer than 20 homes annually are unlikely to achieve the same level of process and pricing efficiencies as a company that builds hundreds of homes each year. There may also be increased costs associated with permitting challenges and delays when adopting PV on multiple properties, which would impact modeled savings. Conversely, economies of scale could influence more cost categories than installation labor, sales and marketing, and PII costs as modeled in this analysis (see Appendix B). Therefore, although the industry is likely to experience some benefit from economies of scale, the scope and timeline of these savings are unclear.

[10] Interviewees cited PV system sizes of 2kW–3 kW as common for new housing construction, smaller than NREL's assumed average U.S. residential retrofit size of 5.7 kW.

[11] Future home energy demand may be influenced by increasing energy efficiency and electrification. Given the uncertainty surrounding these countervailing trends, optimizing PV systems according to a standard size will likely pose a challenge through 2030.

7 Conclusion

We project that 3.3 million residential roofs will be replaced or built each year in the continental United States from 2017–2030, representing a significant market opportunity for residential rooftop PV installers. These two market segments also present considerable rooftop PV cost-reduction opportunities, including four key opportunities that we analyze: market maturation, product innovation, business model integration, and economies of scale.

We apply various combinations of these cost-reduction opportunities to model four pathways to low-cost residential PV in 2030: less-aggressive and visionary pathways in the roof replacement market, and less-aggressive and visionary pathways in the new home construction market. We find that the two visionary pathways—which maximize the savings potential from the four cost-reduction opportunities—could meet or nearly meet the SETO 2030 residential PV target. Specifically, the new construction visionary pathway achieves the 5 ¢/kWh LCOE target, and the roof replacement visionary pathway almost achieves it.

Our analysis has two key implications. First, because installed-system soft cost reductions account for about 65% of the LCOE reductions in 2030 for both visionary pathways, residential PV stakeholders may need to emphasize these soft cost reductions to achieve the 2030 target. Second, capturing these savings will likely require considerable innovation in the technologies and business practices employed by the PV industry.

There are various challenges to achieving the necessary innovations. For example, business model integration, particularly across solar and roofing companies, is critical to reducing the significant sales, marketing, labor, and overhead costs associated with the current PV retrofit business model. This type of business model integration will likely require increased education and cross-training for PV installers, roofers, and homebuilders. At the same time, homebuilders, PV installers, and roofing companies will likely require clear examples of the benefits of business model integration before embracing it widely.

Extensive use of fully integrated PV and roofing products is also crucial to our modeled pathways. However, although integrated products have been, or are being developed, significant investments in research, development, time, and effort will be required to produce the type of low-cost integrated product envisioned in our analysis.

Finally, achieving economies of scale throughout the PV supply-installation chain is important for achieving our pathways. Additional research is needed to clarify the cost savings that economies of scale could provide, especially because of the considerable PII hurdles that must be addressed to realize these benefits.

References

APPA (American Public Power Association). 2017. “Stats and Facts.” Accessed December 2017. https://www.publicpower.org/public-power/stats-and-facts.

Ardani, K., G. Barbose, R. Margolis, R. Wiser, D. Feldman, and S. Ong. 2012. *Benchmarking Non-Hardware Balance of System (Soft) Costs for U.S. Photovoltaic Systems Using a Data Driven Analysis from PV Installer Survey Results*. NREL/TP-7A20-56806. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy13osti/56806.pdf.

Ardani, K., E. O’Shaughnessy, R. Fu, C. McClurg, J. Huneycutt, and R. Margolis. 2017. *Installed Cost Benchmarks and Deployment Barriers for Residential Solar Photovoltaics with Energy Storage: Q1 2016.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-67474. https://www.nrel.gov/docs/fy17osti/67474.pdf.

BNEF (Bloomberg New Energy Finance). 2017. *Bloomberg New Energy Finance PV Module Maker Tiering System*. New York: BNEF. https://data.bloomberglp.com/bnef/sites/4/2012/12/bnef_2012-12-03_PVModuleTiering.pdf.

CertainTeed. 2017. “Apollo II.” Accessed December 2017. https://www.certainteed.com/solar/products/apollo-ii/.

Chung, D., C. Davidson, R. Fu, K. Ardani, and R. Margolis. 2015. *U.S. Photovoltaic Prices and Cost Breakdowns: Q1 2015 Benchmarks for Residential, Commercial, and Utility-Scale Systems*. NREL/TP-6A20-64746. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy15osti/64746.pdf.

DOE (U.S. Department of Energy). 2016. *The SunShot Initiative’s 2030 Goal: 3¢ per Kilowatt Hour for Solar Electricity*. DOE/EE-1501. Washington, DC: DOE. https://energy.gov/sites/prod/files/2016/12/f34/SunShot%202030%20Fact%20Sheet-12_16.pdf.

DOE (U.S. Department of Energy). 2017. “SunShot Incubator Program.” Accessed December 2017. https://energy.gov/eere/sunshot/sunshot-incubator-program.

EIA (U.S. Energy Information Administration). 2015. *Annual Energy Outlook 2015.* Washington, DC: EIA. https://www.eia.gov/outlooks/archive/aeo15/.

EIA (U.S. Energy Information Administration). 2017a. *Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2017*. Washington, DC: EIA. https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf.

EIA (U.S. Energy Information Administration). 2017b. “2015 RECS Survey Data.” Accessed December 2017. https://www.eia.gov/consumption/residential/data/2015/.

Emrath, P. 2014. *Typical American Subdivisions*. Washington, DC: National Association of Home Builders. https://www.nahb.org/-/media/Sites/NAHB/SupportingFiles/8/Typ/TypicalAmericanSubdivisionFINAL_20140902080612.ashx?la=en&hash=A722B42C2C0FBB51BF30DCCD78C458EA6B179FE0.

Feldman, D., and M. Bolinger. 2016. *On the Path to SunShot: Emerging Opportunities and Challenges in Financing Solar*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-65638. http://www.nrel.gov/docs/fy16osti/65638.pdf.

Fu, R., D. Chung, T. Lowder, D. Feldman, K. Ardani, and R. Margolis. 2016. *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016*. NREL/TP-6A20-66532. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy16osti/66532.pdf.

Fu, R., D. Feldman, R. Margolis, M. Woodhouse, and K. Ardani. 2017. *U.S. Solar Photovoltaics System Cost Benchmark: Q1 2017*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-68925. https://www.nrel.gov/docs/fy17osti/68925.pdf.

GAF. 2017. "DecoTech Roof-Integrated Solar System." Accessed December 2017. https://www.gaf.com/roofing/residential/solar.

Gagnon, P., R. Margolis, J. Melius, C. Phillips, and R. Elmore. 2016. *Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment*. NREL/TP-6A20-65298. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy16osti/65298.pdf.

Goodrich, A., T. James, and M. Woodhouse. 2012. *Residential, Commercial, and Utility-Scale Photovoltaic System Prices in the United States: Current Drivers and Cost Reduction Opportunities*. NREL/TP-6A20-53347. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy12osti/53347.pdf.

Grow Solar. 2017. "Permitting." Accessed December 2017. http://www.growsolar.org/permitting/.

GTM and SEIA (Greentech Media Research and Solar Energy Industries Association). 2016. *U.S. Solar Markets Insights*. Washington, DC: SEIA. https://www.seia.org/research-resources/solar-market-insight-report-2016-year-review.

InterNACHI (International Association of Certified Home Inspectors). 2017. "InterNACHI's Standard Estimated Life Expectancy Chart for Homes." Accessed December 2017. https://www.nachi.org/life-expectancy.htm.

James, T., A. Goodrich, M. Woodhouse, R. Margolis, and S. Ong. 2011. *Building-Integrated Photovoltaics (BIPV) in the Residential Sector: An Analysis of Installed Rooftop System Prices*. NREL/TP-6A20-53103. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy12osti/53103.pdf

Lennar. 2017. "New Home Solar Systems." Accessed December 2017. https://www.lennar.com/mylennar/resource-center/article/benefits-of-solar.

NREL (National Renewable Energy Laboratory). 2017. "Annual Technology Baseline and Standard Scenarios." Accessed December 2017. http://www.nrel.gov/analysis/data_tech_baseline.html.

O'Shaughnessy, E., K. Ardani, D. Cutler, and R. Margolis. 2017. *Solar Plus: A Holistic Approach to Distributed Solar PV*. NREL/TP-6A20-68497. Golden, CO: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy17osti/68371.pdf.

Professional Builder. 2016. "2016 Housing Giants Rankings." *Professional Builder*, May 4, 2016. https://www.probuilder.com/2016-housing-giants-rankings.

Shiao, M.J., C. Honeyman, T. Heggarty, J. Jones, N. Litvak, S. Moskowitz, B. Attia, B. Gallagher, A. Mond, M. Parikh, A. Perea, C. Smith, and T. Zin. 2017. *Q1 2017 Solar Executive Briefing*. Boston: Greentech Media Research.

Solar Power World. 2017. "2017 Top Solar Rooftop Contractors." Accessed December 2017. https://www.solarpowerworldonline.com/2017-top-solar-rooftop-contractors/.

SunPower. 2017. *Top New Home Builders Choose SunPower to Advance California's Net Zero Compliance Goals Before 2020: SunPower Installs Solar at 1,000th New Home Community*. Press release, June 27, 2017. http://newsroom.sunpower.com/2017-06-27-Top-New-Home-Builders-Choose-SunPower-to-Advance-Californias-Net-Zero-Compliance-Goals-Before-2020.

Tech Home Builder. "Mandalay Homes and sonnen Partner for World-Class Community." *Tech Home Builder*, November 2, 2017. http://techomebuilder.com/emagazine-articles-1/mandalay-homes-and-sonnen-partner-for-world-class-community.

Tesla. 2017. "Solar Roof." Accessed December 2017. https://www.tesla.com/solarroof.

Woodhouse, M., R. Jones-Albertus, D. Feldman, R. Fu, K. Horowitz, D. Chung, D. Jordan, and S. Kurtz. 2016. *On the Path to SunShot: The Role of Advancements in Solar Photovoltaic Efficiency, Reliability, and Costs*. NREL/TP-6A20-65872. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy16osti/65872.pdf.

Appendix A: Quantifying Residential PV Potential from 2017–2030

The technical potential for residential rooftop PV from 2017–2030 in the rooftop replacement and new construction markets will be influenced by a wide variety of factors, such as population growth and consumer decisions. Our analysis is meant to generate plausible estimates of PV potential for the two segments by state, but we acknowledge the uncertainties related to market development over the analysis period.

Determining the technical potential of the roof replacement market is the most challenging owing to the impacts of roofing materials and climate on roof replacement timelines. For example, asphalt and composite shingles have an average lifetime of 25 years, whereas a properly maintained ceramic tile roof may last 70 years in a dryer climate, or 35 years in a wetter climate, before needing substantial maintenance (Table 4).

As a result, quantifying rooftop PV potential in this segment requires attention to the age of the home, its roofing material, and its location. The U.S. Energy Information Administration (EIA 2017b) tracks the type and age of residential housing stock by census region in the 2015 Residential Energy Consumption Survey (RECS). The focus of this analysis is on the single-family detached home market, which represents 73.9 million homes or about 63% of residential buildings in the United States (EIA 2017b). RECS tracks the age of this housing stock by census sub-region and decade from 1950–2015. These data are disaggregated into yearly builds using a time-series approach. There are 20.8 million homes, or about 28% of single-family detached housing, built before 1950. To incorporate this housing stock into our analysis, we assume that all these older houses were built between 1940 and 1949; much of this housing was likely built earlier than 1940, but this assumption enables us to consider older homes in our analysis of roof replacement schedules.

RECS tracks the market penetration of certain residential roofing materials by census region, and we use these data and the age of housing stock to estimate roof replacement schedules. Overall, shingles (composite or asphalt) are the most common residential roofing material used in the United States, followed by metal, wood, and ceramic or clay tiles (Figure 8). The percentage of the market captured by each roofing material varies regionally, and this variation relates to the impact different climates can have on roofing materials. For example, in very hot and dry climates, clay tiles perform better and can last much longer than asphalt or composition shingles. Thus, although ceramic or clay tiles cost more than traditional shingles do, they capture a larger market share in the West than in other regions (Figure 8).

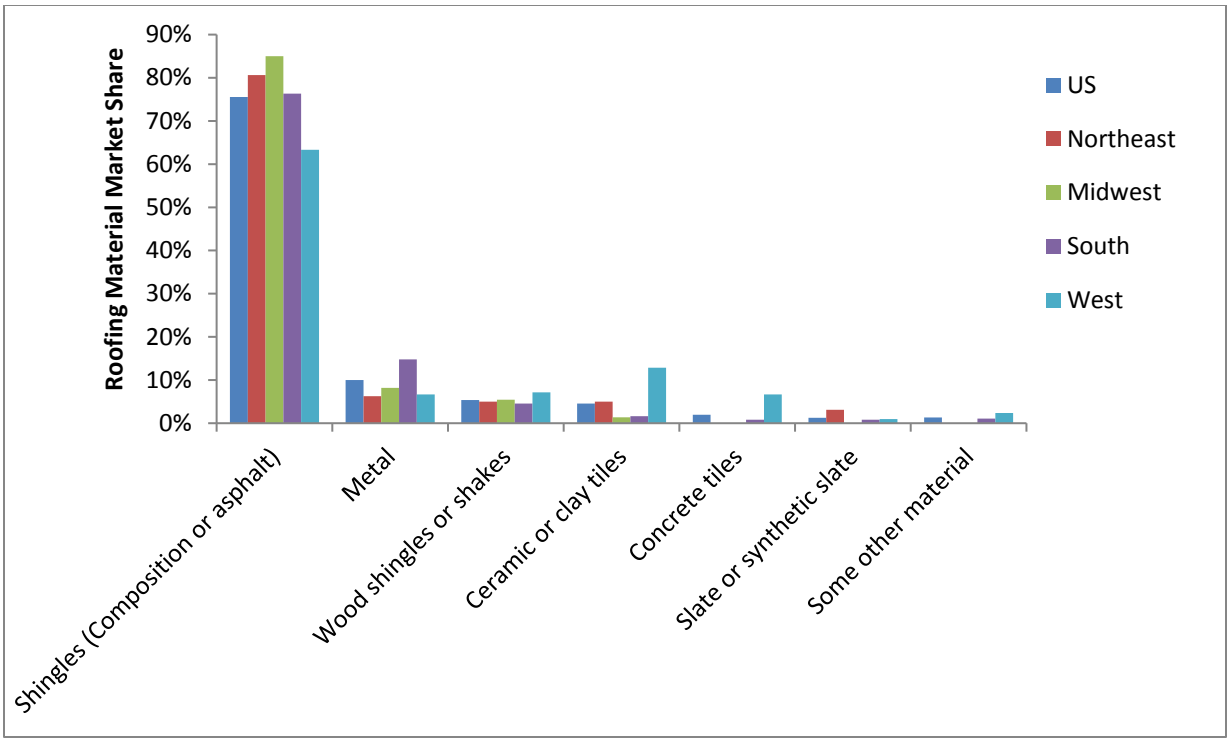


Figure 8. Residential roofing material market penetration nationally and by census region, 2015 (adapted from EIA 2017b)

Although RECS tracks roofing material penetrations regionally, it does not break out roofing material by housing type (single-family homes vs. apartment buildings, etc.). Thus, we apply the regional roofing material market penetrations (as reflected in Figure 8) proportionally to all single-family detached homes by state. In addition, RECS does not track roofing material penetrations based on building stock age. Finally, EIA does not have historical data on roofing material composition prior to 2009. This is problematic because roofing material composition and lifetimes have evolved over time, which can impact when existing homes are likely to require roof replacement. Nevertheless, to provide an estimated timetable for roof replacement, we assume that every home has had the same roofing material composition reflected in the 2015 RECS survey throughout its life. We then assume each roof is replaced in accordance with the current roofing material lifetimes listed in Table 4, which are based on InterNACHI (2017) and interviewee input.

Table 4. Vetted Estimates of Roofing Material Lifetimes by Type and, in Some Instances, Region

Roofing Material	Vetted Lifetime (years)	Regional Variation
Shingles (Asphalt or Composition)	25	
Metal	60	
Wood	25	
Ceramic or Clay	35 or 70	In wet climates (Northeast, South, and Midwest), underlayment likely needs to be replaced about every 35 years; in dryer climates (West), 70 years.
Concrete	35 or 70	In wet climates (Northeast, South, and Midwest), underlayment likely needs to be replaced about every 35 years; in dryer climates (West), 70 years.
Slate	100+	
Synthetic Slate	70	
Other Material*	25	

* "Other material" roof lifetimes can vary by region. For this analysis, roofs on all homes with this material are assumed to last 25 years. In general, roofing lifetimes can vary significantly based on installation quality, material quality, proper maintenance, climate, and homeowner decision-making.

We use this method to estimate a roof replacement schedule for each single-family detached home by state. Not all existing homes are suitable for PV owing to shading or lack of sufficient roof space, among other barriers. Gagnon et al. (2016) estimate the percentage of unsuitable homes by state, and we remove these homes from our analysis accordingly. We then tally the remaining homes expected to require a roof replacement from 2017–2030 and average them to provide an annual estimate by state.

We apply two approaches to translate roof replacements into residential PV technical potential by state. The first is the most aggressive and assumes that each roof replacement maximizes PV deployment; for this we use the estimates of maximum residential PV potential by state made by Gagnon et al. (2016). Although maximizing PV capacity and thus generation may become more common in the future, today residential PV system sizes are smaller, at about 5 kW. Therefore, we include a second estimate based on this smaller system size to offer a more conservative estimate of PV potential. We average the estimated potential capacities across the study period to calculate an annual average market potential in GW. To estimate generation, we apply average PV capacity factors by state.

Because our analysis makes several important assumptions that likely do not reflect the true roof replacement market, the results should only be considered a rough approximation. Table 5 shows our key assumptions for the roof replacement market by state.

Table 5. Key Assumptions for the Roof Replacement Market by State (2017–2030)

State	Potential Retrofits	PV Suitability	Suitable Retrofits	Annual Average Retrofits	Annual Capacity (GW) Conservative	Annual Capacity (GW) Aggressive
AK*						
AL	608,912	83%	507,630	36,259	0.18	0.36
AR	341,961	83%	284,902	20,350	0.10	0.20
AZ	738,185	81%	599,087	42,792	0.21	0.42
CA	3,862,123	88%	3,391,722	242,266	1.21	2.44
CO	691,011	74%	510,763	36,483	0.18	0.27
CT	466,030	75%	350,999	25,071	0.13	0.23
DC	79,004	81%	63,699	4,550	0.02	0.04
DE	110,424	79%	86,936	6,210	0.03	0.06
FL	2,390,697	91%	2,174,105	155,293	0.78	1.69
GA	1,195,830	80%	956,628	68,331	0.34	0.64
HI*						
IA	510,506	82%	419,613	29,972	0.15	0.28
ID	209,919	74%	154,377	11,027	0.06	0.10
IL	2,005,142	83%	1,655,400	118,243	0.59	1.09
IN	1,038,954	83%	859,804	61,415	0.31	0.59
KS	473,472	83%	393,260	28,090	0.14	0.26
KY	555,533	80%	445,691	31,835	0.16	0.29
LA	535,747	89%	477,248	34,089	0.17	0.36
MA	887,611	73%	648,125	46,295	0.23	0.47
MD	697,807	82%	570,428	40,745	0.20	0.36
ME	173,499	73%	126,369	9,026	0.05	0.10
MI	1,555,098	79%	1,225,989	87,571	0.44	0.80
MN	898,962	76%	682,085	48,720	0.24	0.41
MO	992,286	83%	823,450	58,818	0.29	0.54
MS	374,205	85%	317,710	22,694	0.11	0.22
MT	130,022	72%	94,250	6,732	0.03	0.07
NC	1,176,857	80%	946,927	67,638	0.34	0.64
ND	123,438	75%	92,841	6,632	0.03	0.07
NE	310,587	82%	254,375	18,170	0.09	0.16
NH	173,931	73%	126,429	9,031	0.05	0.10
NJ	979,361	78%	762,692	54,478	0.27	0.49

NM	221,636	84%	186,465	13,319	0.07	0.13
NV	313,127	73%	228,637	16,331	0.08	0.12
NY	2,161,981	79%	1,714,884	122,492	0.61	1.17
OH	1,819,193	81%	1,472,236	105,160	0.53	0.95
OK	448,993	87%	392,149	28,011	0.14	0.29
OR	402,789	80%	322,603	23,043	0.12	0.23
PA	1,399,790	80%	1,125,999	80,429	0.40	0.78
RI	137,658	77%	106,555	7,611	0.04	0.06
SC	575,406	83%	477,911	34,137	0.17	0.33
SD	140,945	81%	113,771	8,127	0.04	0.08
TN	832,766	81%	675,044	48,217	0.24	0.47
TX	3,188,461	89%	2,852,544	203,753	1.02	2.04
UT	380,544	72%	275,728	19,695	0.10	0.18
VA	975,628	80%	776,724	55,480	0.28	0.51
VT	81,388	74%	60,446	4,318	0.02	0.05
WA	717,125	75%	535,318	38,237	0.19	0.38
WI	905,136	79%	719,496	51,393	0.26	0.48
WV	212,377	76%	160,544	11,467	0.06	0.11
WY	73,023	79%	57,610	4,115	0.02	0.04
Total	39,275,078		32,258,199	2,304,157	11.52	22.13

* Alaska and Hawaii are not included in this analysis, because there were insufficient data to determine PV capacity potential in the Gagnon et al. (2016) data set.

Estimating the PV potential for the new construction market relies on a different methodology. EIA (2015) models new single-family detached housing builds by census region across five scenarios in the 2015 Annual Energy Outlook. Of the five scenarios, the reference case is considered the base case, and we use this case to determine the total new, single-family detached homes built across each state.[12]

As we do for the roof replacement market, we assume that not all new homes will be suitable for PV,[13] and we use the same suitability rates for the existing housing market to determine PV potential through 2030. We sum the total suitable homes by state and average them to calculate yearly builds. Then we apply the same capacity and generation methods used in the roof replacement analysis. Table 6 shows our key assumptions for the new construction market by state.

[12] The Annual Energy Outlook reference case data were disaggregated to each state using the University of Virginia's state population projections http://demographics.coopercenter.org/national-population-projections/, and then the growth was projected through 2030 using a time-series approach.
[13] It is possible that all new homes could be designed to maximize PV access, thereby increasing the market estimate for this sector.

Table 6. Key Assumptions for the New Construction Market by State (2017–2030)

State	New Homes	PV Suitability (%)	Suitable Homes	Annual Average Builds	Annual Capacity (GW) Conservative	Annual Capacity (GW) Aggressive
AK*						
AL	294,539	83%	245,547	17,539	0.09	0.17
AR	255,608	83%	212,958	15,211	0.08	0.15
AZ	505,167	81%	409,977	29,284	0.15	0.29
CA	1,358,154	88%	1,192,733	85,195	0.43	0.86
CO	378,232	74%	279,571	19,969	0.10	0.15
CT	117,358	75%	88,390	6,314	0.03	0.06
DC	37,286	81%	30,062	2,147	0.01	0.02
DE	64,885	79%	51,084	3,649	0.02	0.04
FL	1,428,220	91%	1,298,827	92,773	0.46	1.01
GA	724,527	80%	579,600	41,400	0.21	0.39
HI*						
IA	143,830	82%	118,222	8,444	0.04	0.08
ID	116,789	74%	85,888	6,135	0.03	0.06
IL	394,359	83%	325,574	23,255	0.12	0.21
IN	202,878	83%	167,895	11,992	0.06	0.11
KS	141,906	83%	117,866	8,419	0.04	0.08
KY	264,373	80%	212,100	15,150	0.08	0.14
LA	375,928	89%	334,880	23,920	0.12	0.25
MA	214,412	73%	156,562	11,183	0.06	0.11
MD	406,993	82%	332,700	23,764	0.12	0.21
ME	44,019	73%	32,062	2,290	0.01	0.02
MI	297,961	79%	234,902	16,779	0.08	0.15
MN	270,072	76%	204,917	14,637	0.07	0.12
MO	298,758	83%	247,924	17,709	0.09	0.16
MS	180,362	85%	153,132	10,938	0.05	0.11
MT	68,828	72%	49,892	3,564	0.02	0.03
NC	700,127	80%	563,339	40,239	0.20	0.38
ND	31,571	75%	23,745	1,696	0.01	0.02
NE	89,718	82%	73,480	5,249	0.03	0.05
NH	46,194	73%	33,578	2,398	0.01	0.03
NJ	205,013	78%	159,657	11,404	0.06	0.10

NM	151,803	84%	127,714	9,122	0.05	0.09
NV	222,332	73%	162,341	11,596	0.06	0.09
NY	439,413	79%	348,542	24,896	0.12	0.24
OH	347,958	81%	281,596	20,114	0.10	0.18
OK	326,080	87%	284,797	20,343	0.10	0.21
OR	137,101	80%	109,808	7,843	0.04	0.08
PA	284,704	80%	229,018	16,358	0.08	0.16
RI	34,138	77%	26,425	1,888	0.01	0.02
SC	332,674	83%	276,307	19,736	0.10	0.19
SD	40,175	81%	32,429	2,316	0.01	0.02
TN	405,016	81%	328,308	23,451	0.12	0.23
TX	2,385,145	89%	2,133,861	152,419	0.76	1.53
UT	211,120	72%	152,969	10,926	0.05	0.10
VA	576,842	80%	459,239	32,803	0.16	0.30
VT	20,978	74%	15,580	1,113	0.01	0.01
WA	246,959	75%	184,349	13,168	0.07	0.13
WI	179,334	79%	142,553	10,182	0.05	0.09
WV	115,236	76%	87,111	6,222	0.03	0.06
WY	38,660	79%	30,500	2,179	0.01	0.02
Total	16,228,560		13,430,512	959,322	4.80	9.31

* Alaska and Hawaii are not included in this analysis, because there were insufficient data to determine PV capacity potential in the Gagnon et al. (2016) data set.

Appendix B: Detailed Cost Modeling Results and Assumptions

To understand the opportunity for achieving ultra-low PV system costs by 2030, we model four cost-reduction pathways. Each pathway was developed by adjusting system cost inputs based on the four key cost-reduction opportunities. Table 7 compares the system costs for each of the four modeled pathways in relation to the Q1 2017 benchmark.

Three of the 11 categories are not impacted by the cost-reduction pathways referenced in this study, including module, inverter, and electrical BOS. Nevertheless, we model savings from the Q1 2017 benchmark in 2030 for each of these categories. The cost savings for hardware (i.e., module and inverter price reductions) are driven by expected savings from technology advances through 2030 as outlined in Woodhouse et al. (2016). Electrical BOS is also reduced 15% to represent assumed incremental savings in wiring and electrical equipment needed for PV through 2030.

Six of the 11 categories are influenced directly by the cost-reduction opportunities envisioned in this report, and the key assumptions behind these modeled savings are discussed in turn here. Structural BOS costs for both less-aggressive pathways see a 10% reduction from current costs due to incremental improvements in racking. In contrast, the visionary pathways see a 64% reduction in these costs, because racking costs are eliminated with use of an integrated product.

Supply chain costs are reduced by 69% in both less-aggressive scenarios due to eliminating module price and inventory markups. The visionary pathways provide additional savings totaling 87% lower than the Q1 2017 benchmark due to removing shipping costs associated with PV, which are expected to be absorbed by shipping an integrated roofing and PV product.

Direct labor installation costs are reduced by 28%–59% from the Q1 2017 benchmark. The lower end of the savings spectrum is based on incremental installation labor savings paired with collaboration between roofing and PV contractors. The higher end assumes that a PV division is integrated with a homebuilder, enabling one team to install PV and roofs on new construction, with additional savings from economies of scale.

PII cost savings for the roof replacement market result from streamlining permitting fees from $400 in the Q1 2017 Benchmark to $200 in 2030. Economies of scale savings further reduce PII costs for both pathways in the new construction market; these two pathways see slight variation in savings resulting from the assumption that, in the visionary case, a company installs PV on all new homes and thereby maximizes economies of scale, whereas, in the less-aggressive case, a company distributes PII costs across fewer installations. Even so, this savings is so small it is lost in rounding.

The sales and marketing category is most heavily influenced by the business model integration opportunity. In the roof replacement market, the less-aggressive pathway represents a scenario in which a solar company partners with a roofing company to conduct some sales and marketing. For the visionary pathway, the expectation is that all sales and marketing costs are integrated with an existing marketing budget from the roofing company. The new construction market is generally similar. In the less-aggressive pathway, savings are associated with a solar company

partnering with a homebuilder. In the visionary pathway, PV is integrated, or closely aligned with, a homebuilder's core business. However, the sales and marketing costs for both new construction pathways are lower than the costs for both roof replacement pathways, because the new construction market pathways benefit from reduced design costs due to PV installers having upfront involvement in new home design. The cost variation between the two new construction pathways reflects the higher economies of scale benefit in the visionary pathway compared with the less-aggressive pathway.

The overhead category is predominantly influenced by business model integration. The two less-aggressive pathways leverage the benefit of partnerships with roofing companies as well as incremental cost savings. The two visionary pathways realize the largest overhead savings, because PV is integrated into or closely aligned with a roofing or housing company, requiring little additional overhead.

Finally, the sales tax and profit categories vary by pathway. These values are fixed percentages of the previous cost categories. Thus, this variation results from the method employed as opposed to any direct impact from the cost-reduction pathways.

Table 7. Comparison of Modeled Costs by Category and Pathway in $/Wdc (Percentage Reduction from Q1 2017 Benchmark)

Cost Category	Q1 2017 Benchmark	Roof Replacement Market		New Construction Market	
		Less Aggressive	Visionary	Less Aggressive	Visionary
Module price	$0.35	$0.30 (-14%)	$0.30 (-14%)	$0.30 (-14%)	$0.30 (-14%)
Inverter price	$0.13	$0.10 (-23%)	$0.10 (-23%)	$0.10 (-23%)	$0.10 (-23%)
Structural BOS	$0.11	$0.10 (-10%)	$0.04 (-64%)	$0.10 (-10%)	$0.04 (-64%)
Electrical BOS	$0.20	$0.17 (-15%)	$0.17 (-15%)	$0.17 (-15%)	$0.17 (-15%)
Supply chain costs	$0.39	$0.12 (-69%)	$0.05 (-87%)	$0.12 (-69%)	$0.05 (-87%)
Sales tax	$0.08	$0.06 (-25%)	$0.05 (-38%)	$0.06 (-25%)	$0.05 (-38%)
Direct installation labor	$0.32	$0.23 (-28%)	$0.16 (-50%)	$0.22 (-31%)	$0.13 (-59%)
Permitting, inspection, and interconnection (PII)	$0.10	$0.05 (-50%)	$0.05 (-50%)	$0.04 (-60%)	$0.04 (-60%)
Sales & marketing (customer acquisition)	$0.34	$0.26 (-24%)	$0.09 (-74%)	$0.07 (-79%)	$0.01 (-97%)
Overhead (general & administrative)	$0.31	$0.22 (-29%)	$0.04 (-87%)	$0.22 (-29%)	$0.04 (-87%)
Profit (%)	$0.32	$0.22 (-31%)	$0.18 (-44%)	$0.22 (-31%)	$0.18 (-44%)
Total	$2.66	$1.82 (-32%)	$1.21 (-55%)	$1.62 (-39%)	$1.10 (-59%)



PERMIT POWER

As Cheap as Our Peers

How cutting red tape can lower the cost of rooftop solar and offset rising utility bills

AUTHOR: Talor Gruenwald

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Permit Power is a nonprofit organization making it cheap and easy for American families to power their lives. We do research, education, and advocacy to break down the bureaucratic barriers that get in the way of American families installing rooftop solar, home batteries, and other energy upgrades.

Executive Summary

In the US, the price tag of residential rooftop solar and batteries is expensive relative to other countries. At a median of $28,000 for a 7 kilowatt (kW) system[1], solar in the US is up to seven times more costly to install than Australia and Germany at $4,000[2] and $10,000[3], respectively, resulting in a difference of $18,000 to $24,000 per project. These prohibitively high costs serve as a significant impediment to adoption, where less than one in ten families in the US have rooftop solar[4] compared to one in three in Australia.[5]

At the same time, Americans are facing a growing energy affordability crisis. Utility bills have risen faster than inflation since 2022[6], and are set to continue to rise as utilities request record increases in rates from regulators.[7] As a result, 1 in 7 households are living in energy poverty.[8] Yet today, most Americans are unable to afford rooftop solar to help them cut their energy costs, even though rooftop solar could reduce electricity bills by over 80 percent.[9]

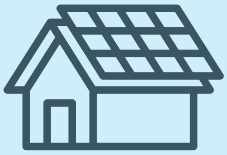
Bureaucratic barriers are some of the primary drivers of high residential rooftop solar costs. In particular, the onerous rooftop solar permitting, inspection and interconnection processes in many areas in the US can add tens of thousands of dollars in direct and indirect costs to each installation.[10]

Bureaucratic barriers driving high residential solar costs



Permitting Inspections Interconnection

If rooftop solar was as cheap as our peers. By 2040:



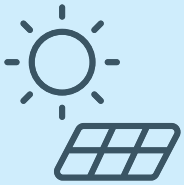
18.2m

more families installing solar



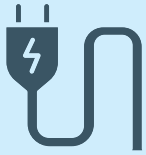
$1,600

average annual bill savings



$1.2t

lifetime savings across all households installing solar



198.2GW

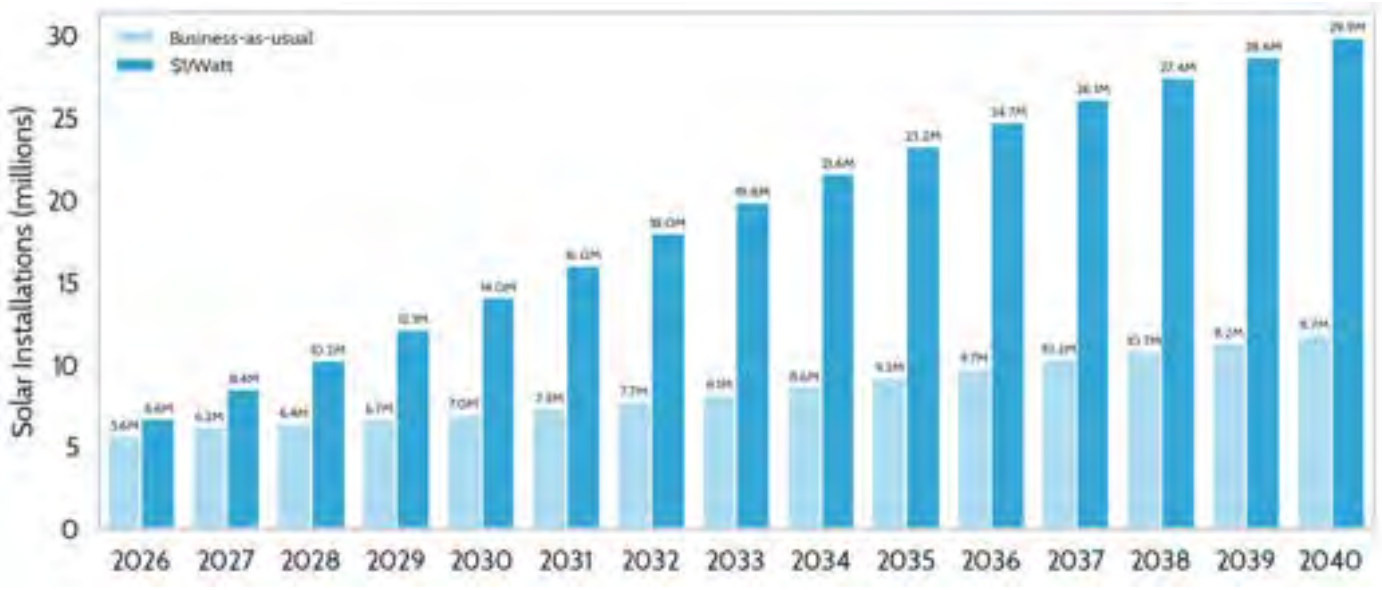
more installed residential rooftop solar capacity

With the passage of the One Big Beautiful Bill Act (OBBBA), residential rooftop solar will become even more expensive after the investment tax credit ends in 2027, putting these cost-saving investments out of reach for even more American families. Wood Mackenzie projects residential solar installs will fall by 46 percent through 2030[11]. This market context makes it all the more imperative to find ways to lower costs and enable households to install rooftop solar.

This report models the additional installations, utility bill savings, and generating capacity that would be realized if decision-makers took action to cut red tape and bring the cost of solar down to where it stands in peer countries. This report finds that, by 2040, total installed prices at levels seen in other countries around the world would yield the following over a business-as-usual scenario:

- 18.2 million more families installing solar – a 155 percent increase
- Annual bill savings of $1,600 for the average family
- An average of $56,000 in savings over the 25-year lifetime of a solar PV system, translating into $1.2 trillion in savings across all households installing solar
- 198.1 GW more installed residential rooftop solar capacity[12]

Figure 1. Solar adoption almost triples by 2040



To lower the price tag for home solar and realize these benefits, policymakers should streamline the permitting, inspection, and utility interconnection processes, including:

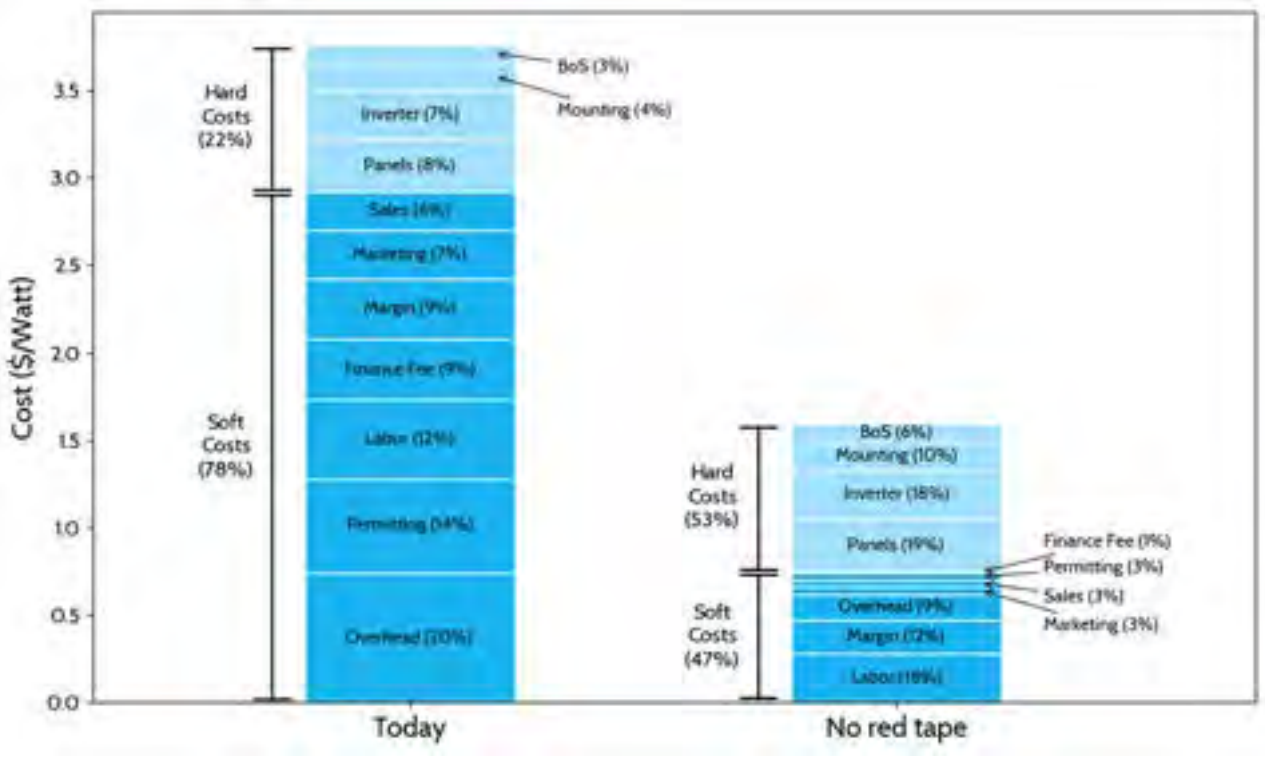
- Adoption of **instant permitting** software or qualified third party permitting to issue instant permits for standard residential solar and battery projects.
- Use of **remote inspection protocols** that allow code compliance to be verified through photos or video submissions for routine residential installations.
- Implementation of **automatic utility interconnection** approvals for qualifying residential systems that use smart inverters and meet established technical screens.
- Updating outdated local government and utility requirements that mandate the installation of unnecessary and expensive hardware, and prevent the use of modern cost-saving technology.

These and other policies to **cut red tape would provide the foundation to allow costs to fall into line with peer countries and 23 percent of US households to get rooftop solar by 2040** compared to 7 percent today.[13] These additional families adopting cheap solar would see their bills decline by 61% on average, an enduring relief from electricity rates that have risen and are projected to continue rising in many areas of the country.

Background: How red tape increases costs

78% of the total installed cost for residential rooftop solar is soft costs

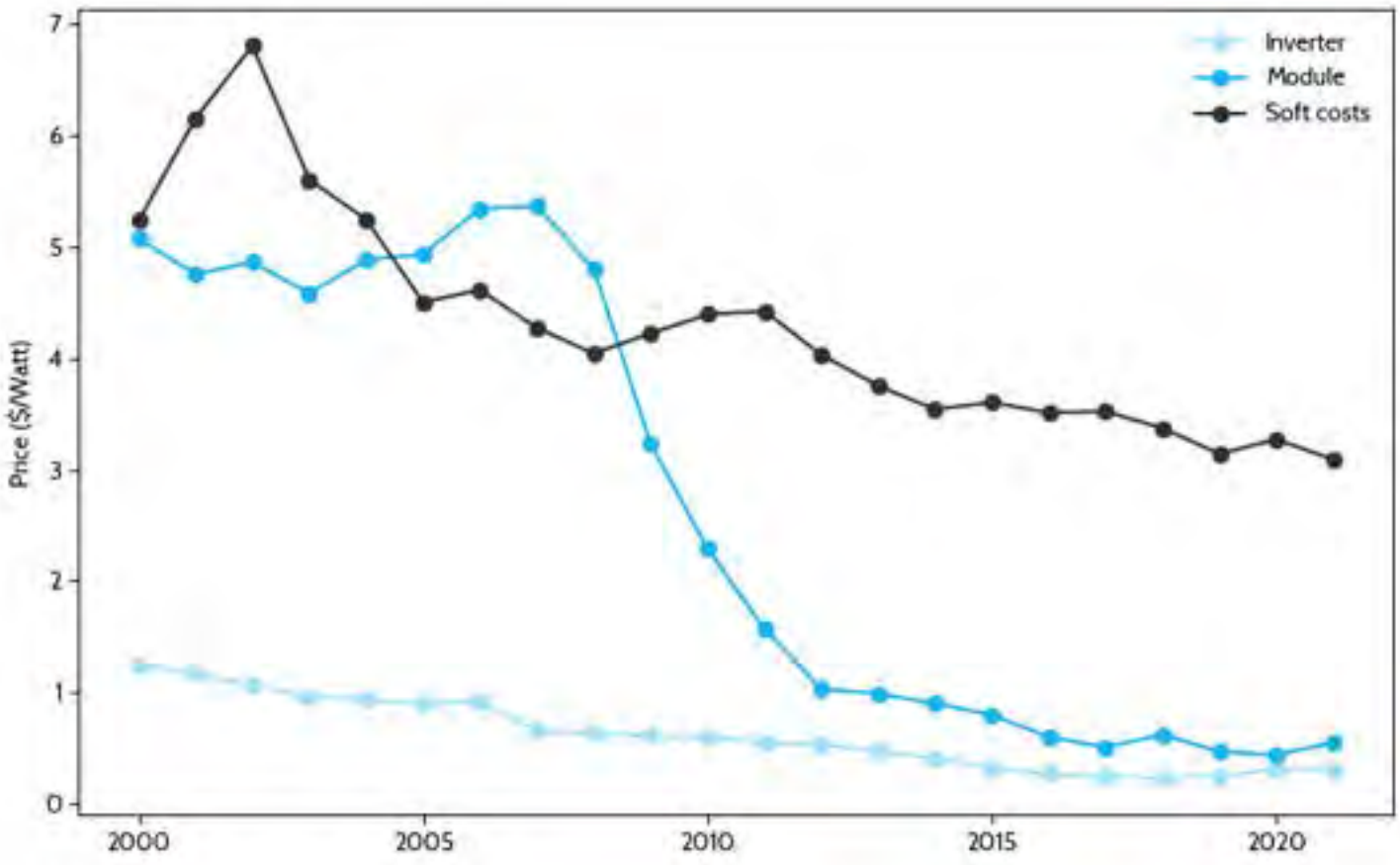
Figure 2. Residential Rooftop Solar Installation Cost Breakdown[14]



Despite hardware costs falling precipitously in recent decades, the share of U.S. residential rooftop solar system prices attributable to non-hardware components—design, project management, sales, permitting, inspections, and interconnection—has grown.

According to OpenSolar, soft costs account for 78 percent of the total installed cost for residential rooftop solar. The direct fees for permits are a small piece; the larger effects come from costs and delays associated with outdated and cumbersome approval processes, such as varying and convoluted permitting requirements across localities, differing requirements between plan reviewers and inspectors within the same jurisdiction, and unresponsive and bureaucratic utility interconnection processes that can stop projects being turned on for months after they have been completed.

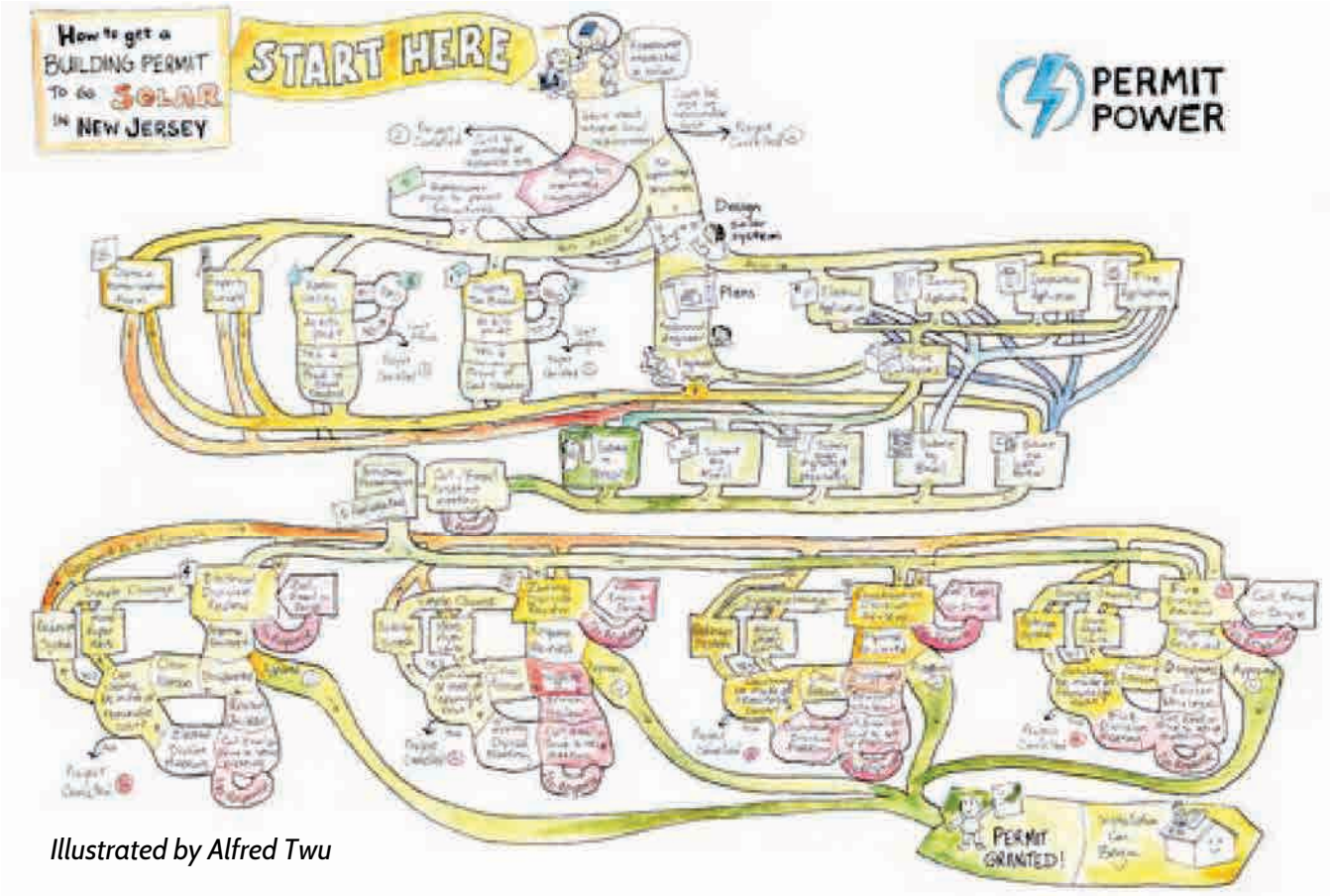
Figure 3. PV system component prices[15]



These delays lead to cancellations that increase costs for all households aiming to get solar, as installers face higher costs of doing business overall. Indeed, installers report rising cancellations as weeks accrue between sale and construction, with industry data suggesting a roughly **10 percent increase in cancellations for each additional week of permitting-related delay.** [16]

The aggregate impact of permitting alone—counting both direct and indirect costs—was estimated at one dollar per watt for residential systems in 2019 and has not changed much since.[17] With total installed cost estimates ranging from $3 to $5 per watt, this represents 20 to 33 percent of the cost of the system, or $6,000 to $7,000 for an average residential system.[18]

Evidence from states



Illustrated by Alfred Twu

Descriptions of byzantine permitting, inspection, and interconnection processes from states help to demonstrate how bureaucracy increases delays and adds costs:

- **Illinois:** Paper submissions of permitting and inspection documents, sequential approvals across departments, and differing documentation requirements for each local government all serve to delay timelines and drive costs.[19]
- **Minnesota:** In-person submission requirements and monthly township meetings for zoning approval delay the start of construction.[20]
- **New York:** Survey requirements, architectural reviews in certain areas, and restrictive battery practices in some localities impede deployment.[21]
- **Colorado:** Bespoke file-naming conventions and mixed paper/digital formats complicate submissions and lead to increased corrections, resubmissions, and delays.[22]
- **New Jersey:** Sequential approvals across different departments and slow, inconsistent processes lead to cancellations and foregone savings.[23]

Results

The analysis uses NREL's Distributed Generation Market Demand (dGen)[24] model to translate a change in total installed price into residential rooftop solar and battery adoption over time. The model compares a business-as-usual U.S. residential price of $4 per watt[25] with a peer-country price case of $1 per watt. $1 per watt represents a rough mid-point between recent estimates of prices in Australia[26] and Germany,[27] and serves as an aspirational cost of residential rooftop solar in the US that could be achieved based on a foundation of eliminating red tape. The model calculates system economics based on install costs, estimates market potential based on those economics, and predicts adoption following typical patterns of market growth.

Top Line Findings

Under the $1 per watt scenario, the modeling projects:

- **18.2 million additional residential solar installations**
- **198.1 gigawatts of additional residential PV capacity**
- **46.2 gigawatt-hours of additional residential behind-the-meter batteries,**
- **$245 billion in additional cumulative savings by 2040 compared to the business-as-usual scenario.**

Over the 25-year lifetime of their rooftop solar system, the average family will save $56,000, resulting in $1.2 trillion in savings across all families installing solar.

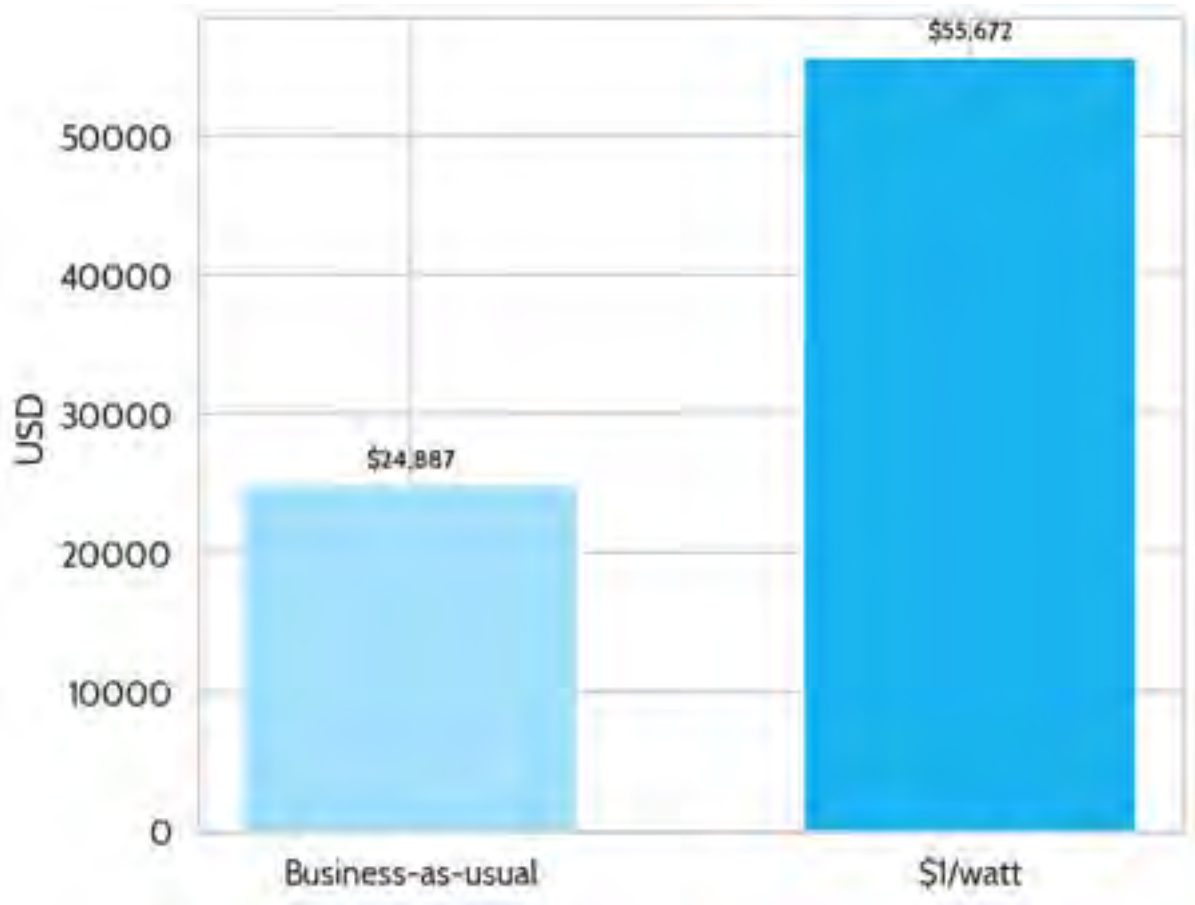
These results indicate that relatively simple bureaucratic reforms can help unlock tens of thousands of dollars in potential savings for households around the country. This is especially relevant in an era where utilities are requesting record rate increases from regulators.

Since 2022, utility rates have increased faster than inflation[28], which exceeded 12 percent between 2022 and 2024.[29] Additionally, in the first half of 2025, utilities requested $29 billion in rate increases[30], which will translate into sharply higher costs for families in the months and years that follow. The Energy Information Administration (EIA) forecasts that rates will be 18 percent higher in 2026 relative to 2022[31], a price shock that can be mitigated with affordable rooftop solar.

Improved household economics

This magnitude of bill savings is enabled by vastly improved project economics for individual households. By 2040, one dollar per watt residential rooftop solar costs yield average payback periods of less than six years, while in the business-as-usual case, average payback periods remain high at 13 years. In addition, households installing solar will save $31,000 more in bills over the 25-year lifetime of their systems by 2040, after taking into account the upfront cost of the system.

Figure 4. Net lifetime savings per household installing solar



Rooftop solar is more economically beneficial in states with higher electricity prices, like California and New York, leading to some of the lowest payback periods by 2040 in the modeling. Aside from shorter payback periods, on average, a family installing solar and batteries will see their annual bills decline 61% by 2040.

Peak demand reductions

Widespread adoption of residential rooftop solar and batteries can help mitigate evening spikes in electricity demand from the residential sector. By storing excess electricity generated from solar panels during the day, batteries enable households to reduce their consumption from the grid in the evening when demand in the residential sector is typically at its highest, contributing to overall reductions in peak demand.

This analysis finds that, if home batteries continue to be paired with rooftop solar at the same rate as they are today, **the additional solar and battery capacity reduces residential sector peak demand by about 21 GW in 2040.** These results demonstrate that distributed solar and batteries can make a substantial contribution to peak demand reduction, supporting reliability and capacity adequacy, and helping reduce costs for all ratepayers.

Certain states, such as Texas and California, see higher battery adoption and thus higher peak demand reductions. Specific dynamics within these states incentivize greater battery adoption and manifest in higher attachment rates.

California

In California, recent reductions in compensation for electricity generated from solar panels have incentivized self-consumption from home batteries to avoid retail electricity purchases during periods with higher prices. This has led to 66 percent of rooftop solar systems in California being installed with a battery between the second quarter of 2024 and the first quarter of 2025.[32]

Texas

In Texas, the ability for residential households to participate in virtual power plants (VPP), or aggregations of home batteries across many households that can then be used as a reliable source of power, is more widespread. Households are compensated for their participation in VPPs. This, coupled with periods where the compensation for exporting electricity generated from panels and stored in home batteries to the grid can exceed $1 per kWh, leads to over 30 percent of rooftop solar systems in Texas being installed with a battery over 30 percent over the same period.

Peak demand reductions are important because increases in peak load drive spending on the electricity transmission and distribution infrastructure that all households will pay for through higher electricity rates. Electricity provided at peak times is also the most expensive. To the extent that adoption of rooftop solar and batteries can reduce peak loads, additional infrastructure investments can be minimized, purchases of expensive peak electricity can be avoided, and upwards pressure on future electricity prices can be reduced.

Policy path: making cheap solar possible

Policy Options

The policy path to cheap solar and batteries focuses on streamlining the bureaucracy that impedes residential adoption of solar and batteries. First, enable instant online permitting for standard residential systems. A rules-based plan check issues a permit immediately when the design meets code, while non-standard projects continue to a manual review. Local governments using SolarAPP+ report fewer back-and-forth cycles and faster starts, reducing median permitting timelines by over two weeks, or 31 percent.[33]

Second, allow remote inspections of completed projects using structured photo or video evidence for routine items. This can reduce repeat visits and truck rolls while reserving in-person time for higher-risk jobs.

Additionally, standardize inspections to focus on components most important for safe operation of the solar and battery system. This approach addresses common friction points documented in state reports, such as sequential approvals across departments and varying document requirements, without reducing safety.

Third, streamline interconnection for standard residential projects to require that households only or processed in parallel with permitting and standard systems can receive permission to operate without extended queues. Pursuing interconnection approval concurrently with permitting and inspection shortens timelines and reduces cancellations linked to long waits after installation.

Pathway to cheap solar and batteries

1. Enable instant online permitting
2. Allow remote inspections
3. Streamline interconnection

Industry changes

These policy reforms can have a material impact on the bureaucratic barriers to residential rooftop solar adoption, but they must be coupled with industry changes to realize more complete cost compression.

Providers have to redesign sales and delivery around digital, self-serve, low-touch motions that the above policies enable. As an example, a report by Tesla on soft costs of residential solar installs points to reductions of $0.57 per watt achievable through customer acquisition and labor improvements—$0.30 from AI implementation that halves commissions and automates project communications, $0.08 from education and transparent, up-front pricing that grows the qualified funnel, $0.09 from tighter install productivity targets, and $0.10 from safety engineering that reduces insurance burden.[34]

Beyond direct soft-cost savings, making rooftop solar and home battery installations cheap and fast unlocks system-wide benefits this analysis does not fully monetize. Distributed generation reduces the cost drivers behind rising retail rates—generation, transmission, and distribution—by shaving peaks, easing transmission congestion, and deferring local capacity upgrades, especially when paired with batteries that make energy available in high-value hours.

Cheaper rooftop solar also improves the economics of electrification: heat pumps, heat pump water heaters, and electric vehicles can utilize midday solar production, cutting household bills. Batteries add resiliency by keeping critical loads powered during outages and, through neighborhood programs or microgrid arrangements, can support nearby homes and essential services.

At the system edge, these resources help serve new loads—from data centers and advanced manufacturing to new housing—without waiting on long-lead central infrastructure. And because solar displaces fossil generation at the margin, particularly peakers, it reduces local air pollution and carbon emissions in communities that often bear the highest exposure. Taken together, these public benefits strengthen the case for policy implementation that cuts red tape impeding solar adoption, even when they are not fully captured in a per-watt cost ledger.



Methodology

Building energy simulations

The foundation of NREL's dGen model is a set of approximately 25,000 building energy simulations sampled from NREL's ResStock database that statistically represent all US households.[35] Each simulation uses location-specific building attributes, weather data, and socio-economic characteristics to model energy consumption for all household end-uses over all 8760 hours of a typical meteorological year. Each simulation also represents the universe of households that can potentially adopt solar based on their roof area, azimuth, tilt, occupancy status, and tenure, with only single-family and small multi-family, owner-occupied homes included. Simulated energy consumption is then calibrated using real world load profiles drawn from utility data. Building and socio-economic characteristics are primarily drawn from the American Community Survey (ACS) Public Use Microdata and the Energy Information Administration's (EIA) Residential Energy Consumption Survey (RECS). More information on ResStock's building energy simulations can be found on NREL's ResStock page and related publications.[36]

Rooftop solar system size and performance

Each building energy simulation utilized by dGen represents between 3,000 and 7,000 households in the real world. Within dGen, rooftop solar system configurations are sized for each building energy simulation to yield the configuration with the highest net present value (NPV). System performance and bill impacts are simulated using NREL's System Advisor Model (SAM)[37], which takes as inputs system size in kW, efficiency in kW per square foot, annual PV degradation, and economic inputs such as total installed costs, utility tariffs, debt fractions of total installed cost, loan interest rates, loan terms, inflation rates, taxes, any incentives, and discount rates to model the hourly generation of a rooftop solar system, resulting electricity bill savings, net present value, and system payback. dGen utilizes Python's SciPy optimize library to search over solar system sizes that vary between 80% and 125% of a given building energy simulation's maximum load to find the NPV-maximizing configuration.

Technology diffusion based on economics

Based on the total installed price input into the model, the optimal configuration estimated by dGen will shift to maximize the NPV of the system. dGen converts these changing project-level economics into adoption over time using a Bass diffusion process. For each building energy simulation (which in turn represents thousands of households in the real world), dGen first translates the project-level economics into a maximum market potential: the fraction of similar households that would ultimately install solar if the given project economics stayed fixed. The specific economic metric used is system payback, which is mapped to maximum market potential from curves drawn from empirical studies.[38] This step sets the ceiling for adoption among the households represented by each building energy simulation.

The model then governs the pace of movement toward that ceiling with a Bass S-curve for technology adoption. Two parameters in the S-curve's mathematical function influence this pace: an "innovation" term (capturing early adopters who move based on economics alone) and an "imitation" term (capturing adopters who move as rooftop solar systems become visible in the peer group). After each year and associated input installed price changes, dGen recomputes economics, updates the maximum market potential, and advances diffusion for every representative building energy simulation. The result is an S-shaped path in which adoption is slow at first, accelerates as visibility rises, and tapers as the representative household approaches its maximum share over time.

Because project economics change over time (for example, as total installed price falls or electricity prices rise), the model must move from one adoption trajectory to another without creating artificial jumps. dGen does this by finding the "equivalent year" on the new trajectory defined by the S-curve—the point that yields the same cumulative market share achieved so far—and then stepping forward one modeling interval from that point. In practice, this means an improvement in economics raises the ceiling and steepens the S-curve, but the adoption path remains continuous rather than spiking in the year of change. dGen also enforces a "no backsliding" rule: cumulative market share cannot fall from one step to the next.

Battery energy storage

After dGen has determined the number of households that will install solar in a given year, the model assigns battery energy storage based on average state-level battery attachment rates between the second quarter of 2024 and the second quarter of 2025, weighted by the number of battery installations in each quarter. Battery attachment rates are drawn from Ohm Analytics data.[39] Batteries are sized according to fixed ratios relative to the rooftop solar system: battery power in kW is equal to the rooftop solar system size in kW. Battery energy storage in kWh is equal to twice the rooftop solar system size in kW. After sizing, the model simulates behind-the-meter dispatch for those households assigned batteries to capture bill savings and peak demand reductions. The model does not take into account VPPs, wholesale market participation, capacity payments, ancillary services, or explicit resilience value for batteries.

Modeled scenarios

Given the above framework, this analysis models two scenarios: business-as-usual, where prices start at $4 per watt and decline at the same rate as NREL's 2024 Annual Technology Baseline for residential rooftop solar[40], and the peer-country price scenario, where prices start at $1 per watt and decline two percent per year thereafter. $4 per watt represents the median installed price according to Lawrence Berkeley National Lab's *Tracking the Sun*[41] data for the year 2024.

In both scenarios, residential rooftop solar project economics were evaluated based on 70 percent debt financing, an interest rate of seven percent, a discount rate of five percent, and an inflation rate of 2.5 percent. The investment tax credit under 25D is applied to rooftop solar in 2026 and 2027 in this analysis. Electricity rates are assumed to increase by three percent annually through 2040.

Bill savings

Each building energy simulation in dGen is assigned a specific utility tariff based on the county associated with the simulation.[42] The tariff is applied to the hourly profile for each simulation under the business-as-usual and $1 per watt scenarios. The hourly charges are aggregated to the annual level, and the difference between the annual aggregations plus the value of all electricity exported to the grid represents the utility bill savings. Export compensation is calculated at an hourly level using county-level hourly wholesale electricity prices prepared by Sun et al. (2025)[43] based on data from the EIA. For each household adopting solar and/or batteries, PySAM projects forward the annual utility bill savings for the 25-year lifetime of the system, taking into account inflation and increases in electricity prices. As "cohorts" of households represented by each building energy simulation adopt solar and batteries over time, the model carries forward their savings based on the projected annual savings output by PySAM.

Peak demand reductions

To calculate peak demand reductions, the model first aggregates the hourly load profiles at the state level under the business-as-usual scenario and the $1 per watt scenario, subtracting any self-consumption from the solar and battery system to produce a net hourly load time series. Batteries are assumed to charge exclusively from rooftop solar generation. The hour with maximum demand from the residential sector in GW is then identified for each state in the business-as-usual scenario. The model then subtracts the demand in GW from the same hour in the $1 per watt scenario state-level net hourly load time series to produce a reduction in peak demand. This describes the reduction in coincident peak for the residential sector alone; the peak hour at the system level may differ from that of the residential sector, depending on electricity consumption patterns in the commercial and industrial sectors, though the residential sector usually drives peak electricity consumption at the system level.

References

1. Permit Power analysis of Lawrence Berkeley National Lab's Tracking the Sun data: https://emp.lbl.gov/tracking-the-sun
2. https://www.solarchoice.net.au/solar-panels/solar-power-system-prices/
3. https://www.ankersolix.com/eu/blogs/balcony-power-plant-with-storage/cost-of-solar-panel-installation
4. https://seia.org/solar-installations/
5. https://www.energy.gov.au/news/australia-hits-rooftop-solar-milestone
6. https://www.eia.gov/todayinenergy/detail.php?id=65284
7. https://powerlines.org/wp-content/uploads/2025/07/0709_PowerLines_Rising-Utility-Bills-Q2-Update-2.pdf
8. https://rmi.org/1-in-7-families-live-in-energy-poverty-states-can-ease-that-burden/
9. Permit Power analysis
10. https://energylibrary.tesla.com/docs/Public/Solar/Retrofit/WhitePaper/en/Tesla_Energy_Breaking_the_Cost_Barrier_in_Residential_Energy.pdf
11. https://www.woodmac.com/press-releases/obbba-policy-changes-could-reduce-us-residential-solar-adoption-by-up-to-46-through-2030-but-massive-long-term-market-potential-remains/
12. https://docs.nrel.gov/docs/fy21osti/80527.pdf
13. https://seia.org/solar-installations/
14. Data for this chart were provided by OpenSolar, a different source than the prices used in the modeled scenarios. As a result, median costs today will not equal $4 per watt
15. Adapted from https://emp.lbl.gov/publications/tracking-sun-pricing-and-design-1
16. https://seia.org/wp-content/uploads/2019/05/Solar-Soft-Costs-Factsheet-1.pdf
17. https://seia.org/wp-content/uploads/2019/05/Solar-Soft-Costs-Factsheet-1.pdf
18. https://aurorasolar.com/blog/what-are-solar-soft-costs-a-solar-industry-overview/
19. http://greenhouse.institute/research/2025/solar_permitting_il/
20. http://greenhouse.institute/research/2025/solar_permitting_mn/
21. http://greenhouse.institute/research/2025/solar_permitting_ny/
22. http://greenhouse.institute/research/2025/solar_permitting_co/
23. http://greenhouse.institute/research/2025/solar_permitting_nj/
24. https://www.nrel.gov/analysis/dgen/
25. Permit Power analysis of Lawrence Berkeley National Lab's Tracking the Sun data: https://emp.lbl.gov/tracking-the-sun
26. https://www.solarchoice.net.au/solar-panels/solar-power-system-prices/
27. https://www.pv-magazine.com/2024/10/24/residential-pv-prices-in-germany-drop-25-within-12-months/
28. https://www.eia.gov/todayinenergy/detail.php?id=65284
29. Permit Power analysis of consumer price index data from the Bureau of Labor Statistics
30. https://powerlines.org/wp-content/uploads/2025/07/0709_PowerLines_Rising-Utility-Bills-Q2-Update-2.pdf
31. https://www.eia.gov/todayinenergy/detail.php?id=65284
32. Permit Power analysis of Ohm Analytics data
33. https://www.nrel.gov/news/detail/program/2024/automated-permitting-with-solarapp-grew-in-2023
34. https://energylibrary.tesla.com/docs/Public/Solar/Retrofit/WhitePaper/en/Tesla_Energy_Breaking_the_Cost_Barrier_in_Residential_Energy.pdf
35. https://resstock.nrel.gov/
36. https://resstock.nrel.gov/
37. https://sam.nrel.gov/
38. https://docs.nrel.gov/docs/fy16osti/65231.pdf
39. https://www.ohmanalytics.com/
40. https://atb.nrel.gov/electricity/2024/residential_pv
41. https://emp.lbl.gov/tracking-the-sun
42. More information on assignment of rates in dGen is available in Sigrin et al (2016).
43. https://www.nature.com/articles/s41560-025-01821-w

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Can cutting rooftop solar costs make up for losing tax credits?

Slow and complex permitting and interconnection rules drive up U.S. rooftop solar "soft" costs. With tax credits going away, fixing them may be existential.



By **Jeff St. John**
23 July 2025



(Justin Sullivan/Getty Images)

Rooftop solar costs way more in the United States than it does elsewhere in the world. That's long been a headache for the sector to navigate. But now with Republicans in Congress killing off the decades-old tax credit for rooftop solar, it's a life-or-death problem.

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navigating complex permitting and interconnection processes that differ from city to city and from utility to utility.

Those costs rise when solar systems are accompanied by batteries, something that is becoming increasingly common as households look for backup power and respond to new incentive structures that prioritize storage, as is the case in California, the nation's largest rooftop solar market.

Big upfront costs are the No. 1 reason Americans decide not to put solar panels on their rooftops. The forthcoming spike in installation costs created by the new GOP megabill will only make that hurdle higher. After this year, households will lose access to tax credits for 30% of the cost of solar, batteries, and other home clean-energy equipment, and companies that offer solar systems under third-party ownership models will face a set of uncertain restrictions that could choke off that part of the market.

In order for the U.S. to keep installing rooftop solar at a healthy rate – something that's key to combatting climate change and helping people manage rising electricity costs and electrify their cars and homes – the industry needs to figure out how to prevent costs from ballooning once the incentives disappear.

"We're now being forced to operate as an industry without subsidies," Birch said. That puts the onus on the industry to both tighten its belt in areas that are under its control and press state lawmakers, local government officials, and utility regulators to reform their parts of the equation.

"We can survive and thrive – if we can reduce soft costs," he said.

Birch, a native Australian known as "Birchy" in the solar world, is working on just that himself.

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There's plenty of evidence that lowering these costs is possible: The soft-cost problem is a bit of a uniquely American phenomenon. In other places with high rooftop solar penetration, like Australia, the world's rooftop solar leader, these costs are far lower.

Solar companies in Australia can quote, sell, and install a 7-kilowatt solar system with a 7 kilowatt-hour battery for about $14,000 in a matter of days, Birch estimated. In the U.S., that same system costs about $36,000, and getting permits and interconnections can take months – long enough to kill a fair number of installs before they can be completed, he said.

Streamlining permitting at cities and counties

When it comes to cutting soft costs, local permitting reform is a big target.

Permitting regulations and processes vary widely across the roughly 23,000 city, county, and other local authorities that have jurisdiction over building permits, electrical code enforcement, and other must-haves for a solar or battery installation. Permitting can add roughly $1 per watt to the cost of a typical solar installation, according to the industry trade group Solar Energy Industries Association (SEIA).

Some do a good job of making the process smooth and straightforward. Others can be far less helpful and efficient. Slow or cumbersome permitting takes a toll on solar installers, stretching the time it takes to complete current projects and move on to the next.

"If you can ensure you're making it through in three weeks versus three months, you're operating much more efficiently," said Barry Cinnamon, CEO of Northern California solar and battery installation firm Cinnamon Energy Systems. On the other hand, "in cities where the permitting is slow, you inevitably get them coming back in two weeks saying, 'You're missing a dash in that form – send it back,' and then two or three weeks later saying, 'We're not sure the battery can go in that spot. Try again.'"

It's hard to standardize permitting across local authorities, which range from well-staffed big-city departments to tiny towns with one or two people working on it. But software that can

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dramatically sped up permitting without sacrificing quality, the platform was made available at large.

Automated permitting turns multiple back-and-forth processes into a "one- to two-page digital form," Birch said. Code standards groups like Underwriters Laboratories and the International Code Council have signed off on SolarAPP+, and similar automated platforms from startups and from city permitting departments are now providing similar same-day options.

The advantages of instant permitting are so great, Cinnamon said, that he's stopped doing projects in cities and counties that don't offer some form of it. With less than six months to finish projects that can secure tax credits, "we don't have the time" to spend elsewhere, he said.

The next step is to expand instant permitting from hundreds to thousands of cities and counties by taking on statewide permitting reforms, said Nick Josefowitz, CEO of Permit Power, a nonprofit advocacy group.

Over the past several years, states including Democratic strongholds like California and Maryland as well as Republican redoubts like Florida and Texas have adopted solar permitting reform laws, he said. New Jersey lawmakers passed a bill this summer that now awaits Gov. Phil Murphy's signature.

Reform looks different in every state. California set mandates for cities and counties to use instant permitting, while Texas and Florida required cities and counties to allow licensed and credentialed third parties to issue permits and conduct inspections on homeowners' behalf. Colorado's law backed off on mandates but offered incentives for local authorities to deploy

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Greenhouse Institute found that streamlined and instant permitting in Arizona, Colorado, Illinois, Minnesota, New Jersey, New York, and Texas could result in an additional 2 million home solar installations between now and 2030, saving households a collective $100 billion.

The results are good not just for households and solar installers but for cash-strapped municipalities, said Elowyn Corby, mid-Atlantic regional director for nonprofit group Vote Solar, which advocated for New Jersey's newly passed reform bill.

"When you put the onus on municipalities to process these permit applications, that's an enormous drain on their resources as well, especially in lower-income communities where there isn't as much municipal infrastructure," she said. "We're hoping this brings capacity back to local governments."

Streamlining utility interconnection processes

Permits aren't the only solar roadblocks. Utilities also need to approve solar and battery systems at homes connected to their grids before they're allowed to be turned on. Solar installers have long complained that slow or costly interconnection processes are a significant drag on their bottom lines.

"I've heard from some of our installers – and some of the bigger ones – that the interconnection approval process is more of a challenge and a bigger cost than the permitting side," said Ravi Mikkelsen, CEO of Atmos Financial, a financial technology company that connects lenders with solar installers and customers. "Some utilities are better than others, but across the board, this is a major issue."

Interconnection rules are complicated, and utilities apply them differently. But reports from solar installers over the years have highlighted problems ranging from lengthy waiting times and restrictions on new solar hookups to exorbitant costs assessed on homes wanting to interconnect.

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technology advances into account. A 2023 ranking from Vote Solar and the nonprofit Interstate Renewable Energy Council assessed state adoption of interconnection "best practices." The groups gave only New Mexico an A grade and six other states B grades, while marking 13 with an F for lacking any statewide standards.

"We need [regulator] rules about when projects can be fast-tracked, what types of systems when and where can be automated and approved by software," Josefowitz said.

Extreme amounts of rooftop solar can cause problems on power grids designed to carry electrons from big substations to customers.

"But batteries totally change the game on this," he said, enabling homes to store solar power when utility grids don't need it and release it when they're in short supply.

That's why solar companies ranging from nationwide players like Sunrun to regional and local installers are recasting their business approach to include becoming "virtual power plant" providers – active providers of energy and grid resources that help augment the resources that utilities can bring to bear.

Opportunities to earn money for these services are relatively scarce today. But with Republicans in Congress and the Trump administration making it much more expensive and difficult to build more renewable energy to meet the growing demand for electricity, utilities may be well advised to reduce the barriers to installing solar and batteries that can provide it, Mikkelsen pointed out.

"At $2 a watt, you can bring down the cost of your power, and you can save money on electrification," he said. But also, "your battery can be used economically much more frequently and becomes super-valuable to the grid. You want to unlock the power of batteries? You fill them with cheaper electrons."

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Jeff St. John is chief reporter and policy specialist at Canary Media. He covers innovative grid technologies, rooftop solar and batteries, clean hydrogen, EV charging, and more.

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G **Greg Ballantyne**
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Very interesting. My own two stage solar generation and storage residential system installation experience over the last couple of years would make me estimate one third "soft cost" impact that could be eliminated by addressing permitting, utility and /or grid operator "slow walking" and "stiff arming" delays and costs, and local government culture war grandstanding. Coincidently, about the same as the tax credits my projects yielded. But I am aware that community solar and small commercial solar projects face a much higher wave of this sort of idiocy. It would be great to find a path toward accelerating the renewable energy transition in the US in spite of the biosphere killing efforts currently underway.

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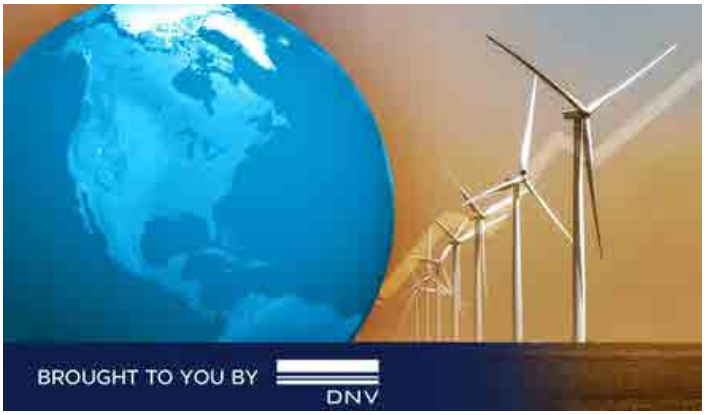


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A 21st-Century Permitting Regime for Rooftop Solar and Home Batteries in Virginia

September 2025

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EXECUTIVE SUMMARY

Between rising home energy consumption and the growth of data centers across the state, Virginia's demand for electricity is threatening to outpace a consistent and affordable supply. As Virginia's energy needs increase, solar and battery systems in homes are going to be ever more valuable for reducing grid strain and improving energy affordability, resiliency and reliability, while protecting our environment. By reducing peak demand and creating a much-needed local energy supply, residential solar and storage technologies are a cost-effective part of a community-oriented grid modernization effort. Many local governments across the country are not set up to efficiently enable this solution, however, and governments in Virginia are no exception. Antiquated steps required at the local level to obtain approval to begin installation add costs to home solar and energy storage systems and increase administrative costs for governments.

Higher costs result in fewer families going solar than otherwise would. In Virginia, 16 percent of residential solar projects that begin the permitting process are canceled before they are completed,[1] largely due to permitting barriers.[2] Households that do install solar likely end up paying more. A recent report by the International Renewable Energy Agency found that the price for residential solar in the United States is roughly double the price in Europe, where permitting barriers have been effectively eliminated.[3] The panels, wires, inverters and batteries being installed in the United States are similar to those used in Europe — much of the difference in cost lies in how these systems are handled by local governments.

2X

Residential solar in the U.S. costs roughly double what it costs in Europe

1-in-6

One-in-six (16%) of residential solar projects in Virginia are canceled before completion, largely due to permitting barriers

Modernizing local government through the use of automated permitting will allow more Virginians to reap the benefits of rooftop solar and energy storage while reducing administrative burdens for localities.

This report relies on firsthand accounts of company representatives currently installing solar across Virginia to uncover some of the common problems facing residential solar and battery storage permitting. It finds that these problems can be resolved through straightforward steps, many of which require few resources for local jurisdictions to implement:

- **Align application submission requirements across jurisdictions and regions.** Installers in Virginia typically operate in several counties at a time and must therefore coordinate with many different jurisdictions, each with its own processes, requirements and preferences. Learning to navigate these systems and tailoring plans to each set of requirements takes staff time and raises costs for customers.
- **Make code interpretations consistent within jurisdictions and across regions.** Interpretations of code requirements can differ among local governments, requiring installers to adapt the content of permit applications to varying sets of rules. Sometimes, even officials within the same jurisdiction disagree with each other about how a code should be interpreted. The multiple resubmissions and project modifications resulting from this ambiguity raise costs and extend timelines.
- **Improve transparency and communication during application review.** Permitting departments are busy, and at times, communication issues leave solar installers in the dark as to the status of their applications and steps required to obtain a permit, exacerbating other problems that may arise during permit review.
- **Shorten review timelines.** It can take a long time to permit residential solar and storage in Virginia. The median wait for obtaining a permit in the Commonwealth is nine business days, with an additional 13 business days to get through an inspection, amounting to a month in all.[4] This is the median — actual timelines can be much longer. In some cities and counties, the typical permitting wait time is 18 to 24 business days.[5]
- **Right-size permitting fees.** Rooftop solar permit fees vary widely in Virginia but can reach several hundred dollars. While high fees are a barrier in themselves, fee variations between governments also present challenges, making it difficult for solar companies to plan and set expectations for the customer.
- **Update third-party inspection programs**. Building department inspections can be time-consuming, resource-intensive and out of line with the requirements set by plan reviewers. Third-party inspection programs in Virginia address some of these issues, but the programs receive little use due to limited access, shortcomings in program design and high variation between building department requirements.

Streamlining the solar permitting process is an easy, local and rapidly scalable solution for getting more clean energy into our communities while saving families and local governments time and money.



POLICY RECOMMENDATIONS

State and local governments should make it easier, faster and cheaper for families to install code-compliant rooftop solar and energy storage systems while protecting health and safety.

One of the most effective ways to do so is to issue permits through an automated permitting platform that expedites the process without compromising quality or safety. Automated permitting platforms ask the contractor a series of questions to verify that the solar system's design is up to code and then approve the permit application automatically, allowing installation to begin.

The most common automated permitting platform is Solar Automated Permit Processing+ (SolarAPP+), which was developed by the U.S. Department of Energy's National Renewable Energy Laboratory in 2019 and is now run by the nonprofit SolarAPP+ Foundation.[6] Since SolarAPP+ launched in 2021, 277 cities and counties in 16 states across the country have adopted the platform.[7] Many other cities and counties offer automated solar permitting using private-sector platforms such as Symbium or by building their own software.[8]

Virginia should also update its third-party inspection program for solar. Local governments should allow contractors to use qualified third parties at their discretion, and the Commonwealth should set the qualification requirements for third parties. Third parties should also be able to use remote inspection tools.

DELAYS IN VIRGINIA'S PERMITTING

MEDIAN WAIT TIMES

2 weeks
for a permit

2.5 weeks
for inspection

1+ month
total for for permitting + inspection



INTRODUCTION

Virginia's electric system is experiencing unprecedented load growth in the 2020s, but the Commonwealth lacks a clear plan for how to meet the demand for additional energy. In 2023, the Commonwealth had more net imported electricity than any other state in terms of megawatt-hours.[9] A 2024 report from the Joint Legislative Audit and Review Commission projected that unrestricted data center growth would double Virginia's electricity demand within a decade, a projection in line with analysis from the regional grid operator PJM.[10] Nine of the 13 states within the PJM region are net importers of electricity, indicating a level of reliance on out-of-state electricity that is not sustainable.

VIRGINIA HAD MORE NET IMPORTED ELECTRICITY IN 2023 THAN ANY OTHER STATE IN THE U.S.

Virginia's peak demand is also rising. In 2024, Dominion Energy recorded six new all-time peak demand records across its service territory in the Commonwealth.[11] In the first month of 2025, it set records three more times. In traditional grid planning, energy flows in only one direction (from power plants to consumers). As peak demand increases, the grid must expand its ability to serve, often with more and larger power lines.

Local distributed energy resources (DERs), such as residential solar and battery storage, can help the Commonwealth address its energy challenges. In contrast to other ways to generate electricity, DERs offer affordable, reliable energy[12] while helping to offset peak demand and reducing the need for ratepayers to fund expensive electric grid expansion projects. Additionally, by alleviating grid congestion, DERs further help defer, reduce or eliminate distribution-system upgrade costs. DERs can come online more quickly than fossil fuel–based generation systems, and depending on how they are set up, they provide resiliency benefits in the event of an electrical outage. A new Virginia law created a virtual power plant pilot program: a network of decentralized DERs that can provide capacity and services to the grid to lower ratepayer costs in other ways. Residential solar and energy storage systems are expected to play a major role in this program.[13] For Virginia to fully harness the benefits of virtual power plants, the Commonwealth needs to have ample distributed solar and storage capacity installed.

The cost of solar technology has fallen dramatically over the last 15 years, making it a more viable option for consumers. But permitting remains a significant obstacle to widespread residential solar and battery deployment in Virginia. Cumbersome and uncertain permitting processes discourage the adoption of solar and increase costs.

The Solar Energy Industries Association (SEIA) estimates that permitting and related bureaucratic costs, such as in-person inspections, add $6,000 to $7,000 to the typical residential solar system.[14]

Wait times of multiple weeks and months also deter families looking to install solar and battery systems and lead to cancellations, which total more than one in seven projects (16 percent) once the permitting process begins.[15] The median wait time for a solar permit in Virginia is nine business days, meaning that half of all solar customers in the Commonwealth wait longer than two weeks for a permit.[16] Some jurisdictions have even longer wait times. In Loudoun County, for example, the median timeline is 16 business days — more than three weeks. One in four permit applicants in the county wait more than 24 business days. In Loudoun, approximately 31 percent of homeowners who begin the solar permitting process end up cancelling the project. In Carroll County, 34 percent are cancelled. SEIA estimates that a one-week delay in system installation due to permitting, inspection, and interconnection processes increases the cancellation rate by 10 percent.[17] It is possible to improve these processes — to reduce costs, speed up timelines, and help more families go solar — while also supporting the integrity of permit review and inspection.





During the permitting process, the plan review of residential solar and battery storage installation ensures that the project is built to code and doesn't create health or safety risks. However, this review can be slow. Approval might be contingent on arcane clerical specifications that have no bearing on the function of the system. It might include requirements unrelated to health and safety. Frequently, the processes and rules are unclear. In some cases, different reviewers may have a different understanding of the same code. Inconsistent permit review processes among or between jurisdictions can add costs and delays. Accelerated adoption of solar in recent years is straining the capacity of local jurisdictions to process permit applications efficiently. As solar and storage systems become more common in homes, local governments can adapt to this growing preference, just as they have with other appliances and technologies in decades past.

Widespread adoption of new technologies often requires local governments to take a different approach. By automating the review of residential solar and storage installations, jurisdictions can streamline the permitting process for solar consumers and installers. Automated permitting allows installers to instantly verify whether an installation meets electrical and building codes and receive a permit immediately. It also reduces staff time at local jurisdictions by removing the need for individual permit reviews. All this can be done without changing the rigor of the application review, ensuring that safety remains a guiding principle of the permitting process.

The most commonly used automated permitting solution is SolarAPP+, a platform developed by the National Renewable Energy Laboratory with funding from the U.S. Department of Energy and now administered by the nonprofit SolarAPP+ Foundation. There are other automated permitting software options on the market as well, such as Symbium, and some local governments have developed their own. A handful of Virginia jurisdictions have already streamlined their solar permitting process using these platforms. Culpeper County and the city of Harrisonburg currently use SolarAPP+.[18] Prince William County, a jurisdiction with which the solar industry engaged early on to update the permitting process, adopted the platform in late 2024.[19]

Updating automated solar permitting processes can allow for faster installations, reduce the cost of a solar system by thousands of dollars and increase homeowner satisfaction. More efficient processes also benefit local building departments, as staff can shift their attention to more complex projects.

AN OVERVIEW OF PERMITTING IN VIRGINIA

There are two phases to the traditional permit approval process for a residential solar system in Virginia. First, the installer contracted to build the system submits plans to the city or county in which the property is located for review, generally to the building department. Reviews are designed to ensure that solar panels and batteries are installed safely and do not pose a threat to homeowners or others. Plan reviewers typically take into account whether the solar contractor has the correct licenses to perform the work, whether the project complies with applicable building and electrical codes and whether the project is properly designed in relation to the electrical grid.

Most cities and counties have their own processes and requirements, though the fundamental standards are rooted in the state's electrical and building codes. When a reviewer determines that a plan does not meet the code or fails to fulfill some other requirement, the plan is sent back to the installer for revision. This back and forth can be time-consuming, driving up costs in both staff time and fees for resubmission. Some small governments outsource the plan review process to a third party. The permit is issued when the system is approved by reviewers, with turnaround times ranging from one day to several weeks. The contractor pays the permitting fee.

After receiving the permit, the installer is cleared to install the system, which typically takes only one to three days. In the second phase of the approval process, the installer must coordinate with the local government to schedule an inspection. The role of the inspector is to verify that the installation conforms with the plan and meets building codes. While the inspection itself takes only around an hour, the total timeline for this phase can be several weeks. In Virginia, the median wait time between the request for an inspection and the inspection itself is 13 business days.[20]

Automated permitting allows localities to automate the plan review phase. The installer submits information pertaining to the system to an online portal that contains all the safety codes and standards required. If any item in the plan is out of compliance, the portal instantly informs the installer and gives them the opportunity to revise and resubmit. If a submission is compliant, the installer receives approval immediately.

The most common automated permitting platform, SolarAPP+, also provides checklists to help inspectors verify installation procedures and adherence to the approved design.[21] This process has the potential to make inspections far more consistent and standardized.

In addition to obtaining a permit and system approval from the local government, the installer needs to go through a parallel process with the local utility to obtain approval for interconnection with the electrical grid.



COMMON PERMITTING ISSUES AND PROPOSED SOLUTIONS

This report considers common issues that local solar installers encounter through the residential solar and battery storage permitting process and explores how automated systems can improve this process. In the development of this report, the authors consulted solar installers and local permitting authorities to discuss the issues that impact their ability to help families in Virginia efficiently and affordably obtain solar systems. While some governments in Virginia have already adopted automated permitting, the following discussion focuses primarily on those still employing traditional permitting processes. We propose solutions to some of the most common problems reported in the Commonwealth.

Align application submission requirements across jurisdictions and regions

Residential solar and storage installers in Virginia typically operate in several counties at a time and must therefore coordinate with many different jurisdictions. One installer said he worked with 95 different jurisdictions. Each of these governments has its own processes, requirements and preferences, making the permitting landscape difficult to navigate. In some cases, project managers spend more time preparing plans to upload for review than they do actually designing the system.[22]

Nearly every local government has its own permitting software, portal (or paper forms) and permit applications. For solar installers, this means managing scores of different logins, systems and jurisdiction-specific requirements. Frederick County, for instance, requires a mail-in application and in-person pickup, which for many installers turns a seemingly simple administrative task into a four- to five-hour round-trip drive.[23] Spotsylvania and Rappahannock require plans to be saved to a thumb drive and sent in the mail.[24] While most jurisdictions require an electrical permit application, some jurisdictions, such as Loudoun County,[25] require a building permit application as well. Others require only a solar permit application.[26]

Jurisdiction-specific administrative requirements present other challenges. For instance, while most Virginia jurisdictions require a structural engineering stamp on plan submissions, the city of Lynchburg requires a stamp from an electrical engineer as well.[26] Henrico County does not require any engineering stamps.[28]

Permitting variability hampers the growth of solar generally by increasing compliance costs and permitting timelines. Learning to navigate permitting systems takes time, as does preparing the plans to meet highly detailed specifications. Standardizing these requirements would save homeowners money.

Make code interpretations consistent within jurisdictions and across regions

Just as clerical requirements differ among local governments, so do interpretations of code requirements, so installers must adapt the content of each permit application to varying sets of rules. For example, some jurisdictions require critter guards to keep birds, squirrels and other animals from entering the spaces between solar panels and a roof; other jurisdictions have no such requirement.[29]

Sometimes, plan reviewers and inspectors working within the same jurisdiction disagree with each other about how a code should be interpreted, which results in inconsistent feedback and can be frustrating for installers. "Some solar interpretation issues are so misunderstood that officials across the state disagree with each other on whether certain installation methods are mandatory or prohibited," said an installer based in Falls Church.[30]

In especially thorny cases, resolving disagreements over code interpretation requires an appeal to the Virginia State Building Code Technical Review Board (SBCTRB).[31] Once issued, the SBCTRB's interpretations are legally binding for all jurisdictions. The Falls Church installer recalled an inter-jurisdictional dispute about a grounding and bonding issue that was ultimately resolved by the SBCTRB.[32] He noted that one jurisdiction said, "You have to bond the ground in the neutral. You must do it." Other jurisdictions said, "I forbid you from doing it." The SBCTRB issued an interpretation to settle the issue.

Plan reviewers and inspectors might disagree as well. Another installer remarked, "Inspectors don't always agree with the reviewers, or they'll add in additional things from the code that the reviewer has already approved. There's a disconnect there, and they don't usually pick up the phone and talk to one another."[33] The installer added that some inspectors will fail an inspection if stickers aren't placed in certain ways, even if a reviewer has already approved the plan. In other cases, inspectors dispute previously approved electrical wiring plans, claiming they are not up to code.[34] In these situations, the installer is stuck in the middle and is responsible for talking to both parties to reach a resolution.

Sometimes an installation involves a system product that is not commonly used or known in the area. In such cases, the contractor or manufacturer and the permit reviewers might not agree on whether the product is compliant with the current code. The delays and resubmissions that result from these misunderstandings generally add costs. They can also be very frustrating on the customer side and on the installer side. One installer explained that he had a plan rejected because the reviewer was not familiar with the racking included and assumed it was not a code-compliant product.[35] In fact, the racking was code compliant, and the manufacturer had to step in to resolve the issue.

"We were sitting for like seven weeks trying to submit and paying these $90 fees over and over again, not knowing what the heck they were talking about," the installer recounted.[36] "It turned out that they just didn't know what that trademarked product was, and they assumed it was something different and weren't giving us good feedback." He added, "Code-enforcing officials are oftentimes not adequately confident in their ability to determine a proposed solar system's compliance with the Virginia Uniform Statewide Building Code (USBC), which can result in failed reviews, requirements to use a third-party inspector or requirements to hire a third-party engineer."

Multiple installers reported that they occasionally deal with a plan reviewer who seems to be resistant to rooftop solar altogether.[37] One installer reported that in 2022, his Fairfax-based company drew up a plan for a customer with a home in Prince William County and submitted it to the county's building development division for review.[38] The structural plan reviewer sent it back for corrections multiple times, claiming that the solar panel spacing and attachments were unsafe. Despite what the installer believed were conservative numbers used to calculate various load factors (such as snow load), reflecting a structurally safe installation method, the plan was not approved and the project was never completed. The customer's neighbor, meanwhile, had no trouble with getting a permit for his solar installation. According to the installer, the primary difference between these two projects was the particular plan reviewer involved.

Improve transparency and communication during application review

Communication issues can also cause aggravation. "One of the largest frustrations is when communication is in the dark," explained one installer. "If you're applying for a permit and you have to mail it in and then two weeks later you haven't heard anything and you have to leave voicemails or play phone tag and you don't know the status of the permit — that's probably my biggest frustration."[39]

Sometimes feedback is unclear, making it hard to make proper corrections. Some plan reviewers issue corrections in the form of difficult-to-understand dropdown or copy and paste comments rather than supplying clear feedback specific to the design in question.[40] Some use opaque language when communicating corrections that installers struggle to understand.[41] Miscommunication can result in high fees, project delays and in some cases cancellations.



Shorten review timelines

All of the challenges detailed so far add delays to what is already, in many cases, a lengthy timeline. The median wait for obtaining a permit in Virginia as a whole is nine business days, with an additional 13 business days to get through an inspection.[42] These are only averages — timelines for local governments and individual projects vary widely. In the cities of Manassas and Waynesboro and the county of Spotsylvania, the median permit timeline is between 16 and 25 business days.[43] Installation and utility approval add additional time.

One installer, whose company works in multiple states, said it takes an average of around 30 days for her company to pull a rooftop solar permit in Virginia, even longer than the statewide average reported by Ohm Analytics.[44] The longest timeline her company experienced was 163 days in Prince William County.

An installer with offices in both Falls Church and Bumpass claimed that reviews in Fairfax County can be lengthy, even though the jurisdiction places an emphasis on quick turnaround. One application in early 2024 was in review for more than two months. Online portal records show that it took four days for the application to move from "plans received" to "accepted for plan review" and another two months to make its way through "review distribution," "building review," "review coordination," and, finally, "permit issuance."[45]

Long timelines can be the result of a high volume of permit applications, staffing issues or both. The review itself takes only around an hour — it's waiting for someone to get around to doing it that slows the process. When asked why the turnaround time for a permit is four to six weeks in her jurisdiction, a representative from Franklin County Development Services said the department was short-staffed.[46] Complicated processes and multiple stages of review also add time.

Tom Grimes, a plan reviewer, is one of around half a dozen staffers at the Loudoun County Department of Building and Development who process solar permit applications.[47] He explained that the permitting process involves multiple steps and multiple departments: It starts with intake by the county's permit coordinators and then moves to the building, electrical, and zoning departments. The county gives each department 10 business days to complete its review. Grimes, who works in the building department, said he tries to expedite solar permit reviews because they are relatively straightforward. He said he typically completes his part of the process within five business days. Still, due to the need for multiple departmental reviews, the median time for permit approval in Loudoun County is 16 business days.[48]

Right-size permitting fees

Rooftop solar permit fees vary widely in Virginia and can reach up to several hundred dollars. High fees are a barrier in themselves, but the variation and lack of transparency also present challenges, making it difficult for solar companies to plan and set expectations for the customer.

At the low end, Blacksburg charges a flat fee of around $30.[49] Permitting fees in Alexandria, by contrast, average $475, and in Manassas, $517.[50] These are median totals, so the actual permitting fees can be much higher. Some governments charge additional fees for every plan correction, and these fees can add up quickly. "I paid $1,350 for a permit in Prince William County," said the Falls Church–based installer. "In South Hill, in the same week, I paid 70 bucks for an electrical permit to put up an equivalent or a similar-sized system." In 2024, Prince William supervisors approved a plan to spend $1.2 million to establish a temporary solar fee reduction program,[51] but the program expired and does not appear to have been renewed.[52]

Update third-party inspection programs

Once the contractor installs the solar system, most building departments send an inspector to the job site to verify that the system is up to code and matches the approved plans. Inspectors generally give a multiple-hour window for their arrival time. If the job site is far from the contractor's office or traffic is heavy, a qualified installation crew member might have to spend half a workday or more on a single inspection. Communication between the contractor and inspector to schedule the inspection can also be poor, and many inspectors do not climb onto rooftops to assess the panels, racking, and mounting hardware due to balance or liability concerns.

Some jurisdictions have too few inspectors. One solar installer reported that the city of Hampton has a single inspector for solar projects. If the inspector is out of the office, the homeowner can wait several extra weeks with the panels on their roof, unable to turn the system on. For some homeowners, the inspection has been delayed three or four times.[53]

As previously noted, plan reviewers and inspectors don't always agree on the requirements for a solar system. During inspection, the plan reviewer is not at the job site, so if the inspector has an issue with the installation, even though the plan reviewer approved it, the installer might have no option but to alter the installation to conform with the inspector's preferences. This can involve significant additional resources.

To alleviate these problems, some Virginia jurisdictions have qualified third parties conduct solar inspections, but these programs have shortcomings. Third-party inspection programs in some jurisdictions do not pertain to solar. When they do, there is often an added net cost. Local rather than state building departments set the qualifications for the third parties, creating a lack of statewide uniformity and consistency. Finally, after the third party inspects the installation, the building department will conduct a review of the third party's assessment, adding a layer of bureaucracy and duplication.[54]

Prince William County SolarAPP+ Success Story

Within Virginia, one jurisdiction stands out from the others for its history of solar permitting obstacles: Prince William County. After years of barriers stymieing the adoption of rooftop solar, the county took initiative to update its review process.

In 2022, Solar United Neighbors, an advocacy organization with roots in Virginia, and the Chesapeake Solar and Storage Association, a Mid-Atlantic trade group, began working with Prince William to simplify its permitting requirements and boost transparency.[55] County officials implemented a series of changes aimed at making the permitting process faster, more efficient and easier for residents, developers and contractors.[56] As part of this initiative, the building department launched a SolarAPP+ pilot program in February 2024. It announced the county's official adoption of SolarAPP+ at the end of October 2024, albeit only for solar (not storage) and with additional requirements.[57]

The county's stated goals include shorter permitting times, reduced costs, process improvements, reduced staff time per project, and faster service.[58] The adoption of SolarAPP+, plus a simplified review process for applications that don't go through SolarAPP+ and greater process transparency, is set to address the past challenges installers faced in applying for residential solar permits in the jurisdiction.





CONCLUSION

Residential solar going mainstream will benefit all Virginians. Getting there will require an "All of Virginia" approach, including updating local permitting processes into a more modern paradigm. Reducing the time and the cost involved in moving a solar project through the permitting process, from application through inspection, is critical to expanding residential solar usage in Virginia. Allowing installers to obtain permits for code-compliant solar systems through an automated permitting platform and to receive a remote inspection from a qualified third party would help this expansion.

Solar installers and localities across the Commonwealth recognize the need for a more efficient system. One installer, when asked what she would do differently, said, "Mandate automated solar [permitting], because the nature of roof-mounted solar tends to be pretty standard." Another installer pointed to application standardization, expedited review times, reduced product confusion, uniform code interpretation, increased code confidence and uniform professional opinions — nearly all of which would be included with the adoption of automated permitting. "It would be great if we could standardize how inspections work too," he added.

Cutting through the red tape of the solar permitting process and allowing for automated permitting will make it easier for solar installers to understand the process, follow the steps, and receive approval of their plans instantly, without the risk of costly delays. It will help more Virginia families enjoy the freedom of going solar, saving them money and reducing air pollution. It will save local governments time and money and help relieve permitting backlogs that can limit the growth of new construction and other industries. Streamlining solar permitting in Virginia will also free up resources to process more solar projects, bringing more energy into the grid to meet demand. The bottom line is that by making residential solar and storage adoption easier, Virginia can realize local grid and energy benefits while reducing harmful pollution at a time when energy affordability and availability are needed the most.

METHODOLOGY AND ACKNOWLEDGEMENTS

Research for this report relied on video and phone interviews with representatives from nine solar companies, whose residential photovoltaic operations together cover the majority of geographical regions in Virginia. Interviewees were typically those most familiar with an organization's permitting practices — usually the company's permitting coordinator. Researchers also reached out to eight local governments with additional questions stemming from discussions with installers (five responded) and reviewed those governments' websites. Representatives who gave feedback included permit technicians, city planners, and electrical inspectors. Interviews took place from October 2024 through September 2025. All names of solar installers interviewed have been omitted from this report.

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CHESSA is the Chesapeake Solar and Storage Association. We are a solar and energy storage trade association committed to an effective and equitable clean energy transition across Maryland, Virginia, and the District of Columbia. A 100% clean energy transition that sees mainstream adoption of local solar, large-scale solar, and battery storage throughout the electric grid will realize a stable and affordable grid for all consumers.

Environment Virginia has one mission: to protect the natural world. We advocate ideas and actions to guide our country onto a greener, healthier path. Our network of 30 state environmental groups promotes clean air, clean water, clean energy, wildlife and open spaces, and a livable climate. Our members put grassroots support behind our research, public education, advocacy and litigation.

Permit Power is a nonprofit organization making it easy for American families to power their lives cheaply. We do research, education, and advocacy to break down the bureaucratic barriers that get in the way of American families installing rooftop solar, home batteries, and other energy upgrades.

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Image Credits

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carlofranco, Golden Hour Residential Solar Panels, Modern Middle-Class Neighborhood, Dense Population (Close Up). Stock photograph. iStock, 2025. https://www.istockphoto.com/photo/green-house-with-solar-panels-modern-middle-class-neighborhood-dense-population-gm2176228167-595732045

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References

1. Average for the period Q2 2022–Q1 2024, drawn from 28 cities and counties for which data are available. Data compiled by Ohm Analytics.
2. Jeffrey Cook et al., "Exploring the Link Between Project Delays and Cancellation Rates in the U.S. Rooftop Solar Industry," National Renewable Energy Laboratory, 2021. https://www.sciencedirect.com/science/article/abs/pii/S0301421521002913?via%3Dihub
3. International Renewable Energy Agency (IRENA), "Renewable Power Generation Costs in 2020," 2021. https://now.solar/wp-content/uploads/2022/09/irena_power_generation_costs_2020.pdf
4. Clean Code, Ohm Analytics. https://cleancode.ohmanalytics.com
5. Data compiled by Ohm Analytics.
6. U.S. Department of Energy, "Streamlining Solar Permitting with SolarAPP+." https://www.energy.gov/eere/solar/streamlining-solar-permitting-solarapp
7. SolarAPP+, "Where Is SolarAPP+ Available?" https://help.solar-app.org/article/108-where-is-solarapp-available
8. Symbium, "In Which Cities and Counties Can I Use Symbium to Secure an Instant Solar Permit?" https://symbium.com/faq/rooftop_solar_ess/in-which-cities-and-counties-can-i-use-symbium-to-secure-an-instant-solar-permit
9. U.S. Energy Information Administration, "Virginia Was the Top Net Electricity Recipient of Any State in 2023." https://www.eia.gov/todayinenergy/detail.php?id=64104
10. Data Centers in Virginia, Joint Legislative Audit and Review Commission, December 9, 2024. LOGOS; Dominion Energy, "Powering a Growing Virginia." https://www.dominionenergy.com/virginia/updates/powering-virginia
11. Dominion Energy, "Powering a Growing Virginia." https://www.dominionenergy.com/virginia/updates/powering-virginia
12. Kyle Richmond-Crosset and Zachary Greene, "How Distributed Energy Resources Can Lower Power Bills, Raise Revenue in U.S. Communities," World Resources Institute, September 30, 2022. Sarah Gledhill, "Understanding the Value of Distributed Energy Resources," Yale Environment Review, March 20, 2023. Clean Energy States Alliance, "Locational Value of Distributed Energy Resources." https://www.cesa.org/projects/locational-value-of-distributed-energy-resources
13. Companion bills HB2346 and SB1100 created a virtual power plant pilot program in Dominion service territory.
14. Solar Energy Industries Association, "Solar Soft Costs," June 2019. https://seia.org/wp-content/uploads/2019/05/Solar-Soft-Costs-Factsheet-1.pdf
15. Average for the period Q2 2022–Q1 2024, drawn from 28 cities and counties for which data are available. Data compiled by Ohm Analytics.
16. These timelines are based on samples; data compiled by Ohm Analytics. Clean Code, Ohm Analytics. https://cleancode.ohmanalytics.com
17. Solar Energy Industries Association (SEIA), "Solar Soft Costs," June 2019. https://seia.org/wp-content/uploads/2019/05/Solar-Soft-Costs-Factsheet-1.pdf
18. "States With the Fast Residential Solar Permitting," GreenLancer, October 24, 2024. https://www.greenlancer.com/post/residential-solar-permitting
19. "Prince William County Launches SolarAPP+ for Home Solar Energy Systems" (press release), Prince William County, October 24, 2024.
20. Clean Code, Ohm Analytics. https://cleancode.ohmanalytics.com
21. SolarAPP+, "What's on the SolarAPP+ Inspection Checklist?" https://help.solar-app.org/article/89-whats-on-the-solarapp-inspection-checklist
22. Zoom interview with president of a Falls Church–based solar company, November 1, 2024.
23. Zoom interview with operations manager for a Maryland-based solar company, October 23, 2024.
24. Google Meet interview with former director of shared services at a Fairfax-based solar company, November 15, 2024.
25. Loudoun County, "Solar Permits," https://www.loudoun.gov/SolarPermits.
26. Video interview with a national solar provider that has operations in Virginia, September 2, 2025.
27. Phone interview with director of operations at a Roanoke-based solar company, October 30, 2024.
28. Video interview with a national solar provider that has operations in Virginia, September 2, 2025.
29. Video interview with a national solar provider that has operations in Virginia, September 2, 2025.

30. Zoom interview with president of a Falls Church–based solar company, November 1, 2024.
31. State Building Code Technical Review Board (SBCTRB), Virginia Department of Housing and Community Development. https://www.dhcd.virginia.gov/state-building-code-technical-review-board-sbctrb
32. Virginia State Building Code Technical Review Board, interpretation 1/2023.
33. Google Meet interview with former director of shared services at a Fairfax-based solar company, November 15, 2024.
34. Google Meet interview with former director of shared services at a Fairfax-based solar company, November 15, 2024.
35. Zoom interview with president of a Falls Church–based solar company, November 1, 2024.
36. Zoom interview with operations manager for a Maryland-based solar company, October 23, 2024
37. Google Meet interview with former director of shared services at a Fairfax-based solar company, November 15, 2024
38. Google Meet interview with former director of shared services at a Fairfax-based solar company, November 15, 2024
39. Zoom interview with operations manager for a Maryland-based solar company, October 23, 2024
40. Zoom interview with president of a Falls Church–based solar company, November 1, 2024
41. Google Meet interview with former director of shared services at a Fairfax-based solar company, November 15, 2024
42. Clean Code, Ohm Analytics. https://cleancode.ohmanalytics.com
43. Data compiled by Ohm Analytics
44. Zoom interview with operations manager for a Maryland-based solar company, October 23, 2024
45. Screenshot of Fairfax County permit review portal, shared via email by president of a solar company based in Falls Church, November 14, 2024
46. Phone call with Franklin County Development Services, November 14, 2024
47. Phone interview with Tom Grimes, building inspector with Louden County, November 15, 2024
48. Data compiled by Ohm Analytics
49. Phone interview with Blacksburg building official, November 12, 2024
50. NREL, "SolarTrace," https://maps.nrel.gov/solarTRACE/
51. Max Marcilla, "Prince Willam Co. Approves Plan to Waive Fees for Residential Solar Panel Installation," DC News Now, August 4, 2023
52. Residential Solar, Prince William County, https://www.pwcva.gov/residentialsolar
53. Phone interview with a national solar provider that has operations in Virginia, July 28, 2025
54. 2021 Virginia Residential Code, Section 113.7
55. Elizabeth McGowan, "Can Cutting Fees and Red Tape Help Lure Solar Companies Back to This Virginia County?," Energy News Network, August 17, 2023
56. Prince William County, "Permitting Process Improvements Initiative" https://pwcworks.pwcva.gov/permitting-process-improvements-initiative
57. "Prince William County Launches SolarAPP+ for Home Solar Energy Systems" (press release), Prince William County, October 24, 2024
58. Prince William County, "Permitting Process Improvements Initiative," https://pwcworks.pwcva.gov/permitting-process-improvements-initiative

Streamlining rooftop solar permitting could cut costs by 61%

Permit Power finds that by reducing bureaucratic barriers to residential solar, nearly 20 million more families in the U.S. could install solar by 2040, leading to $1.2 trillion in lifetime bill savings.

OCTOBER 27, 2025 **ANNE FISCHER**

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SunPower residential rooftop solar installation.

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A recent report by Permit Power, As Cheap as Our Peers: How cutting red tape can lower the cost of rooftop solar and offset rising utility bills finds that by cutting the red tape in rooftop solar permitting, almost 20 million more families would install solar by 2040.

Solar in the U.S. costs up to seven times more to install than in Australia and Germany, according to the Permit Power report. It estimates that in the U.S. the median cost is $28,000 for a 7 kW system, whereas it would be $4,000 in Australia and $10,000 in Germany. These high costs are impediments to adoption, the report notes, with just one in ten families in the U.S. having solar, compared to one in three in Australia.

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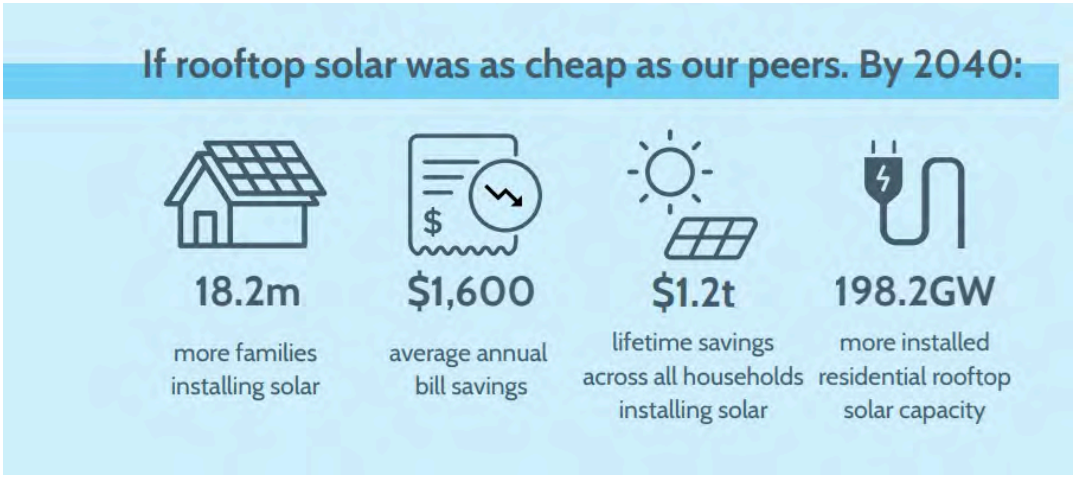


Image: Permit Power

Prior to the passage of the One Big Beautiful Bill Act (OBBBA), people in the U.S. were incentivized to go solar with a 30% tax credit; however, that credit ends at the end of 2025.

The high cost of solar comes at a time when utility bills are rising faster than inflation, with that trend expected to continue, according to Permit Power. The report notes that while one in seven households are living in energy poverty, most cannot afford the high cost of solar, which would help cut their energy costs. Rooftop solar can reduce electricity bills by over 80%, according to the report.

The report finds that if U.S. households could buy rooftop solar at the same price as Australian or German households, almost 20 million more would install solar by 2040. Permit Power estimates they would see average annual bill savings of $1,600, resulting in aggregate electricity bill savings of $1.2 trillion over the lifetime of these additional rooftop solar systems.

Reducing bureaucratic barriers, particularly rooftop solar permitting, inspection and interconnection processes, will reduce installation costs in many areas in the United States, the report finds.

“There is strong research that shows how unnecessary bureaucratic barriers raise the cost of rooftop solar and home batteries in the United States,” said Talor Gruenwald, Research Director of Permit Power and author of the report. “This is the first research that shows the enormous

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benefits that would accrue to American families if we removed those bureaucratic barriers and brought the costs of home solar and batteries down to levels in other peer countries."

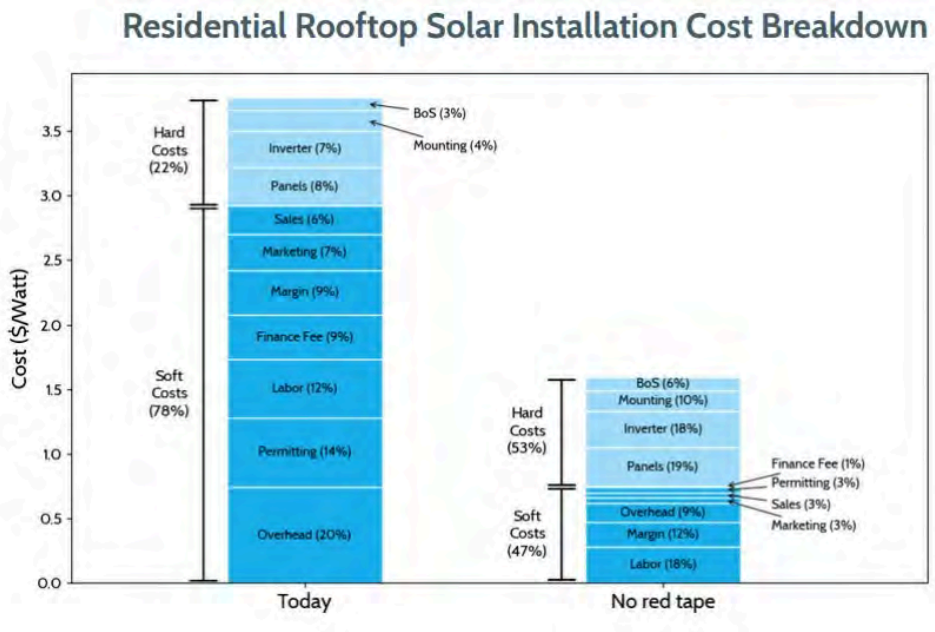


Image: Permit Power

According to OpenSolar, a solar design and permitting software specialist, soft costs account for 78% of the total installed cost for residential solar. These can include what the report describes as "costs and delays associated with outdated and cumbersome approval processes, such as varying and convoluted permitting requirements across localities, differing requirements between plan reviewers and inspectors within the same jurisdiction, and unresponsive and bureaucratic utility interconnection processes that can stop projects being turned on for months after they have been completed."

The solution

The report outlines ways in which policymakers can cut the bureaucratic red tape:

- Adopt instant permitting software or qualified third party permitting to issue instant permits for standard residential solar and battery projects.
- Use remote inspection protocols that allow code compliance to be

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installations.

- Implement automatic utility interconnection approvals for qualifying residential systems that use smart inverters and meet established technical screens.
- Update outdated local government and utility requirements that mandate the installation of unnecessary and expensive hardware and prevent the use of modern cost-saving technology.
- These and other policies to cut red tape would enable 23% of U.S. households to get rooftop solar by 2040, according to the report.

[Also read "Simplify solar volunteer campaign launches across the U.S."]

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Anne Fischer was a senior editor at pv magazine USA. Anne is a seasoned writer, editor, and journalist.
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5 comments

Mark Spohr REPLY

October 28, 2025 at 10:32 am

I can testify that permitting leads to extra costs and delays.
I've gone through the process three times and all three times there were stupid delays and extra costs.
The third time was the worst. My ground based array was significantly delayed leading to loss of a significant power company incentive, mandatory relocation to a less desirable location, and an absurd requirement to install devices written into the regulation by an ignorant consultant. (These fictional devices did not exist anywhere for purchase.)

Jerry Wagner REPLY

October 28, 2025 at 11:01 am

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This report simply confirms & amplifies why cities & towns that want to reduce & stabilize energy costs for ordinary residential & commercial rate payers need to adopt ordinances that streamline rapid deployment of a matrix of widely distributed micro grids, with on-site non-flammable battery storage & Vehicle-2-Grid chargers at existing large parking lots within their jurisdiction. Right where most of us live, work & commute from large apartments & condos to business parks, shopping centers & various municipal facilities. No new utility transmission, site acquisition or other site improvement spending required. And no permitting or interconnection delays or armies of litigious NIMBYS. All the health care & higher education facilities in my county have already covered over 50% of their big parking lots with solar canopies. Mundane Solar Abundance. They're already getting it & fortifying the local distribution grid with it.

Bruce Arkwright

REPLY

October 28, 2025 at 7:09 pm

This is definitely where our all solar associations, industrial and socal, can all come together and help push....there are too many local municipals and different rules to follow... sadly neither helped with the overpriced services solar installers have been charging Americans for the last decade... Now all is going to pay a heavy price because of trump, with a many bankruptcies coming next two years....

Chris

REPLY

October 29, 2025 at 10:50 am

I disagree. California has had a streamlined solar application process and has mandated that municipalities offer "Real Time Solar Issuance" since September of 2024 I believe. The cost on permit fees under I believe 38.4KW is capped at $450. So the chart indicating a 14% permitting cost is inaccurate for CA's market.

The cost of running a business in a highly litigious country/state I imagine contributes to the large overhead 20% vs 9%.

Erika Ginsberg-Klemmt

REPLY

October 29, 2025 at 10:59 am

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Permit Power's findings highlight something GismoPower has been saying for years: The U.S. treats rooftop solar like a mini construction project when, in truth, solar generation can be as simple and standardized as plugging in a dryer or refrigerator.

In countries like Germany and the UK, millions of citizens already buy plug-in solar appliances off the shelf: no permits, no roof work, no red tape. The "Balcony Solar" movement has made renewable energy as accessible as any household device. Meanwhile, in the U.S., outdated permitting rules and utility gatekeeping keep solar locked behind barriers of bureaucracy, inflated costs, and inequitable access.

At GismoPower, we believe it's time for a new category: Plug-In Photovoltaics (Plug-In PV), where solar becomes a consumer appliance, not a construction project. Our Mobile Electricity Generating Appliance (MEGA) is built around this idea: a UL-certified, portable solar carport that plugs into a standard 240V outlet. No roof, no permits, no waiting months for approval, just plug-in power from your own driveway.

Streamlining rooftop permitting is a good start, but it's only a halfway measure. The real transformation will come when Americans can buy, plug in, and power up solar just like any other household appliance. That's how we democratize renewable energy, close the energy poverty gap, and empower every family, homeowner or renter, to participate in the solar economy.

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Streamlining structural engineering compliance of rooftop solar photovoltaic installations using an open-source approach

Nicholas Vandewetering [a], Joshua M. Pearce [b c]

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Highlights

- Regulations often slow solar photovoltaic (PV) penetration velocity.
- Rooftop PV sometimes requires both interpretation and approval from a professional engineer.
- This engineering process is a substantial fraction of the capital costs of small-scale PV systems.
- New open-source tool to streamline the process while maintaining building code compliance.
- Average 5 kW rooftop PV systems cost reduced 5–25% in the U.S. using free tool.

Abstract

Although solar photovoltaic (PV) systems provide the lowest cost electricity, regulations often slow PV penetration velocity. A current hurdle to distributed generation with PV is building code compliance. For example, installing solar PV modules on rooftops in some areas requires both interpretation and approval from a professional engineer. This engineering process comes with costs, which can be a substantial fraction of the capital costs of small-scale systems for smaller or efficient houses, as well as for less-wealthy families that want to build up systems one module at a time. Improving the permitting and inspection process can thus significantly reduce the soft costs of distributed PV systems. This study provides a method of overcoming these challenges for rooftop solar PV by introducing an open-source tool to streamline the process while maintaining compliance with necessary local building codes. The results of economic analysis on this method show costs of average 5 kW rooftop PV systems can be cut by 5–25% in the U.S. Thus, accessibility and affordability of rooftop PV systems are significantly improved because of the elimination of redundant engineering. Implementing such open-source tools is a low-cost effective area of future energy policies to facilitate more economically inclusive and widespread PV adoption.

Previous Next

Keywords

Photovoltaic; Structural analysis; Solar energy; Regulatory compliance; Structural engineering

1. Introduction

Long regarded as the best option for energy for a sustainable society [1], solar photovoltaic (PV) systems are finally the fastest growing energy source [[2], [3]] due to the fact they produce the lowest cost electricity in history [4]. Although, large systems garner the interests of utilities and multinational corporations, a lot of PV growth is fueled by small-scale, distributed, and often rooftop PV that are net metered grid-tied systems [5]. Conventional net metering has been an effective energy policy tool for mass small-scale solar PV development [[5], [6], [7], [8]]) although recent evidence from value of solar calculations show that solar customers are subsidizing their neighbors if only compensated at net metering rates [9]. As a general rule throughout North America, because the cost of solar PV-generated electricity is so low, net metering provides prosumers (producing consumers) a large return on investment (ROI) for relatively small investments as the levelized cost of electricity (LCOE) [10] is lower than the cost of grid electricity when net metered in most locations [9]. In addition, many governments at the national, state and even local levels have provided various forms of energy policies to support PV, which resulted in PV reaching economics of scale and thus further reducing PV capital costs [[11], [12], [13], [14]]. The steady price decreases for PV seen over the last several decades [[12], [13], [15], [16]], are expected to continue for at least an additional 60% over the next several years [17]. Due to the now obvious

economic superiority of PV over conventional sources of power, governments are reducing and eliminating the earlier subsidies [[7], [13], [18], [19], [20], [21]]. Business models are now outdated that rely on utilities only generating profit from providing large centralized power as distributed generation has matured [[22], [23]]. Thus, some utilities that are threatened by competition from their customers [24] (which can produce lower-cost electricity with their own solar rooftops) have begun to approaches including various rate manipulations to restrict distributed PV integration on to the grid [25]. One rather esoteric area of regulation that is being used to reduce the PV penetration velocity [[26], [27], [28]] is building code compliance. Thus, an area normally not considered energy policy, building code policy, is actively hampering PV deployment and slowing the rate of distributed renewable energy production.

In Canada, for example, installing solar modules on rooftops requires strict compliance the National Building Code of Canada (NBCC) [29], and CSA O.86 Engineering Design in Wood [30], often requiring both interpretation and approval from a professional engineer. This engineering process comes with substantial costs, ranging from $900 to $5,000 or more per rooftop [[31], [32], [33]], which substantially limits the accessibility of solar energy to a broad demographic and makes a substantial fraction of the cost for small scale systems. This policy is particularly discriminatory towards potential small solar owners. So, for example, for a 1 kW system for a small residential house that might have a turnkey cost of $3/Wp for all materials and installation costs of $3,000, the engineering check of the house could result in costs from 1/3 to over 100% of the system [34]. The financial burden and red tape of engineering inspections poses a significant barrier to small-scale systems, people in smaller or more efficient houses, or homeowners without access to large quantities of capital that want to build up systems one module at a time (e.g., by using microinverters or DC optimizers). In addition, the increasing demand for solar panel installations has led to a surge in the need for professional engineer inspections, resulting in elevated costs and accessibility issues, such as even getting a timely inspection even if the funds are available to pay for it. Thus, it is clear that improving the policies around the permitting and inspection process can significantly reduce the soft costs of the system [35]. All of these factors are deterrents to the widespread adoption of rooftop PV systems, but most notably of the less affluent. This is intriguing because no energy policy exists that specifically penalizes the poor to deny them the opportunity to install profitable distributed solar, but the building code policy effectively does this in practice.

This study provides a method of overcoming the challenges of de facto energy policy that mandatory engineering approval for rooftop solar PV installations by introducing an open-source tool to streamline the process while maintaining compliance with necessary local building codes. First, a background on the necessary structural analysis is provided. Then the tool design and method are detailed as well as the results of using it. Additionally, the approximate cost savings from avoiding professional engineer inspections is presented. Overall, the open-source system provided in this study provides users an opportunity to conduct a streamlined structural analysis on their rooftop and provides them an outline on how to properly inspect the structure themselves. The existence of this tool provides policy makers with a path to maintaining safety while radically

reducing costs of residential PV. The open-source package, which combines the inspection and analysis processes and delivers them into one complete submission for review, has the potential to save both time and money on typical PV rooftop installations. A case study is presented to show the impact of applying the proposed policy and using the tool on an average Ontario residential home. The results also indicate potential changes in the current demographics of solar ownership by enabling less affluent homeowners to afford PV.

2. Background on structural analysis

Considering the findings by Dwyer et al. that current structural analyses often overestimate the impact of uplift loads due to conservative assumptions (Dwyer et al., 2014), it is justified not to delve into the negligible effects of uplift caused by solar installation. Additionally, because of how slim the PV system of the rooftop is, it is safe to assume that the additional lateral load acting on the roof is negligible. Therefore, only the maximum downwards load case is assessed.

In parallel, to obtain the snow load on the rooftop, the methodology outlined in Vandewetering et al.'s research paper can be applied [36]. By referencing the relevant equations and parameters specified in the appendices of this publication, both the snow and wind loads can be derived. Once the design wind and snow loads are determined, the total design load acting on the rooftop can be established by considering the load combinations outlined in Vandewetering et al.'s appendix [36]. These combinations incorporate the simultaneous effects of dead, wind, and snow loads, all occurring simultaneously. With the total design load identified, users can further analyze the distribution of load among the roof trusses, ensuring that each truss receives an appropriate share of the load based on its tributary width. The total design load on a rooftop, crucial for assessing its capability to support solar panels, is computed by deriving maximum wind and snow loads based on location and the dimensions of the structure. For a detailed explanation on deriving these loads, refer to Appendix A and B of Vandewetering et al. [36].

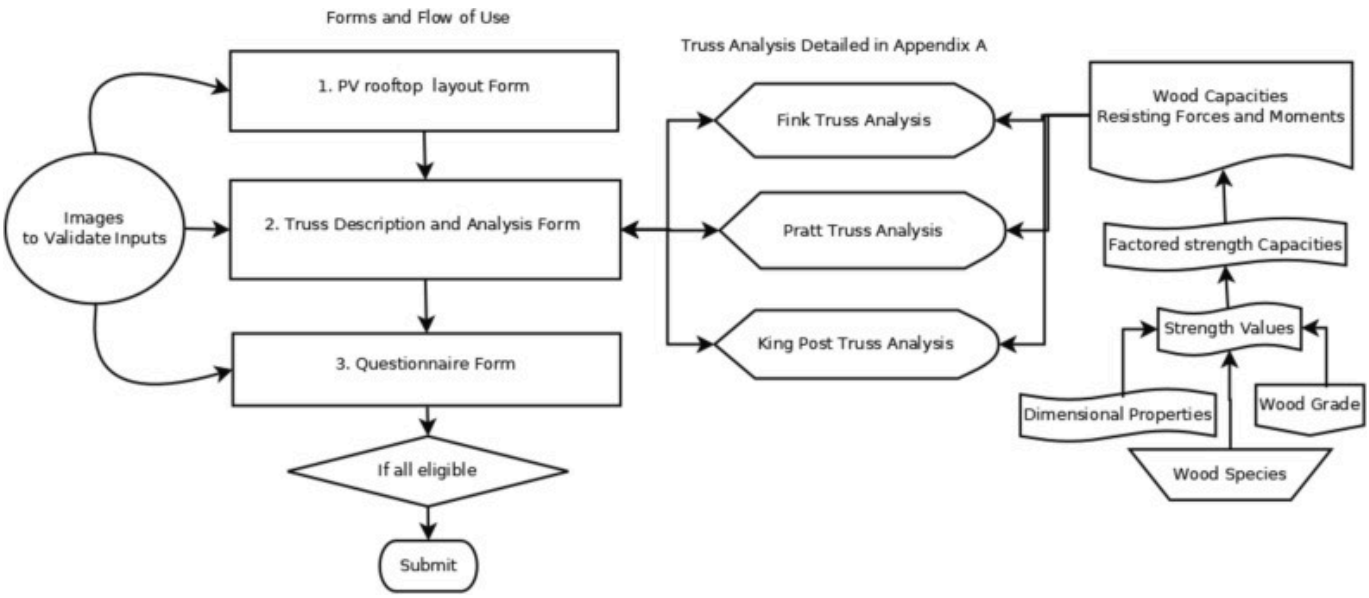
For the dead load of the roof, which typically consists of the self-weight of the trusses, plywood, and shingles, it is common practice that nearly all roof trusses assume a uniform pressure dead load of 10 psf, or 0.48 kPa, acting on the top chords of the trusses. The self-weight of the PV system is usually provided by the PV manufacturer, and can range from 0.17 kPa [37] to 0.24 kPa [38]. For simplicity, even though the PV modules may be installed on just one side of the trusses, an analysis can be conducted where it is assumed that PV modules are installed throughout the entire span of the truss. This provides a conservative analysis that makes the loading on the truss symmetric, which effectively reduces the time spent analyzing the trusses by over 50%.

These loads are then combined with both the self-weight of the roof-top structure, and the weight of the modules. All of these different loads are multiplied by their corresponding factors of safety provided from the NBCC [29], and are then combined. This process is outlined in Vandewetering et al. [36].

3. Open-source package for structural analysis

To overcome the challenges associated with engineering approvals, an open-source package is created and available on the Open Science Framework (https://osf.io/dymp3/) that can calculate the structural engineering compliance of a rooftop, along with presenting all other necessary information about the rooftop to local authorizing officials. This open-source program is developed to enhance the solar installation process and eliminate the need for structural engineering approval for typical residential rooftops. The program can quickly consult both the NBCC [29] and CSA O.86 [30] to determine whether a rooftop can support the additional load of solar panels is feasible.

The open-source package contains three documents that users must fill out in order to be deemed eligible for rooftop installation and are illustrated in a flow chart showing where data comes from is shown in Fig. 1.

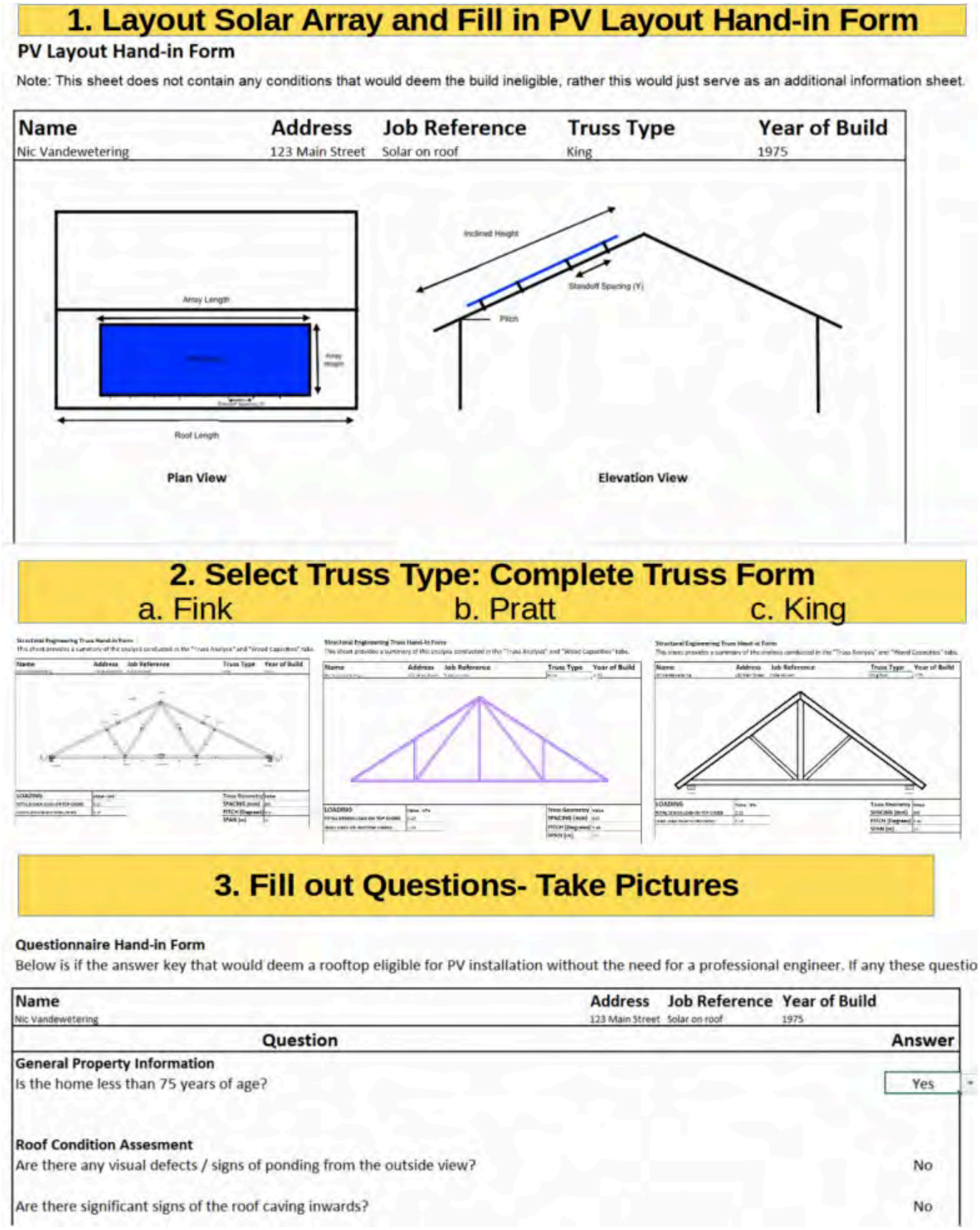


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Fig. 1. Flow chart of Process.

Screenshots of the tool are shown for each page in Fig. 2: 1) a PV rooftop layout form, 2) A Truss Description and Analysis form, and 3) a Questionnaire form. Wood capacities and the actual truss analysis for each of the three types of trusses that are pre-calculated are also included in the tool, but the user does not need to input anything into them.



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Fig. 2. Flowchart of basic steps to use the open source tool to evaluate a roof for PV.

These forms are submitted and attached with sufficient photographs that validate the information provided within the forms. Although the images provide no scientific value, they do provide the information needed to verify the claims in the forms are correct. The package is then sent to local authorities, such as a city or municipal official depending on the jurisdiction. The open-source program, originally built as a spreadsheet, is designed to quickly analyze the structural integrity of a rooftop based on the structural analysis conducted in Appendix A. By plugging in input parameters such as material properties, roof dimensions, and design loads into the sheets, the analysis work that a structural engineer would do is completed in an instant, thus removing the need for solar customers or installers to invest time and money on this process. It should be noted that artificial intelligence is not used in this solution, all equations (Appendix A) are hard coded into the equations contained in the spreadsheet. Each of the three steps will be explained in detail.

3.1. PV rooftop layout form

This form enables users to input the dimensions of their roof section designated for PV module placement, in addition to specifying the size and configuration of the PV array. By providing detailed information and specifications about the desired PV system, as well as the geometry of the rooftop, users are given a comprehensive assessment of their project's feasibility. This form serves as an initial screening tool and analyzes the input data to determine the suitability of the rooftop for standard PV system installation. If the criteria meet the predefined safety and practicality standards of the open-source package, the user is deemed eligible to proceed with the installation. Alternatively, if the project is identified as overly custom or advanced, exceeding the package's standard application capabilities, then the form advises that consultation of a structural engineer is required.

3.2. Truss Description and analysis form

In using this open-source Truss Description and Analysis Form, users will plug in the maximum design loads for their location and geometry as outlined in Appendix A of [36], and then provide basic details of their roof trusses that the PV modules will bear on. The selection of trusses for residential structures is influenced by multiple factors that impact structural integrity, cost-effectiveness, and aesthetic outcomes. Three truss systems are demonstrated in the supporting material: Fink, Pratt and King post trusses. Trusses like the Fink trusses are favored in scenarios requiring extensive spans without intermediate support due to their lightweight and economical design. Additionally, the Pratt truss is selected for its efficient load distribution by strategically making the compression members the shortest members to ensure buckling instability does not occur, thus allowing longer spans and where heavy snow and wind are common. Conversely, King post trusses offer simple and an open concept design for shorter spanning roofs that are easy to fabricate and provide sufficient space for insulation. These values can be easily found by inspecting the trusses in the attic, or by contacting the local municipality for original structural drawings on the home. Many homeowners will have the technical competence to do this themselves, but for the

majority of homeowners, this can be done by professional PV installers as part of the service they provide when installing a system and providing quotes. The form will then calculate the maximum loads acting on critical members of the truss, and will provide a calculated factor of safety, considering the maximum design loads they are to carry, and the additional weight of the PV system. The sheet will then notify the user whether their system is eligible for PV rooftop installation or not. In the background, the sheet conducts a structural analysis on the trusses and determines the ratio of the capacity of the members over the demand as specified by NBCC [29] and CSA O.86 [30]. This streamlines the work that a professional engineer would do, and eliminates unneeded expertise, thus significantly streamlining the process and making rooftop PV installation more feasible.

3.3. Questionnaire form

The open-source PV installation questionnaire is the final tool in assessing rooftop compatibility and is designed for users to provide detailed information regarding the structural and conditional specifics and history of the installation site. Key parameters under that are assessed include the rooftop's age, the existence of any defects in the rooftop's structure, and the status of any applicable warranties. This data is critical for ensuring that the installation does not infringe upon existing material or construction warranties, while also verifying the structural integrity required for safe, efficient, and code compliant PV system operation. The software will then assess eligibility based on whether it is safe to utilize this package without a structural engineer's stamp. Upon successful validation, the system categorizes the installation site as eligible.

3.4. Photographs

In order to validate the information provided in the three forms, users must complete a visual inspection of their rooftop and provide photos to their local authorities. Critical aspects of their rooftop's structure and condition must be captured to ensure the information on the forms matches real life. The specific photos required within the package are:

(1) A Typical Truss View: This photo should be taken from the attic, offering a clear view of the truss structure to gauge the standard construction framework of the house.

(2) A Typical Connection of the Trusses: This photo assesses the structural integrity and the potential for load-bearing failures.

(3) An Elevation Photo of the Rooftop: This photo is best achieved via drone photos or from taking a photo from a higher vantage point on the roof (e.g., the use of a ladder). This photo provides a comprehensive view of the rooftop's layout and overall condition.

(4) Visible Defects: Any observable defects, from damaged shingles to areas showing signs of water damage, must be documented. These images are crucial for evaluating

the suitability and safety of proceeding with a solar panel installation.

(5) Typical Bearing connections: This photo must capture the bearing surface and the truss in contact with this surface.

(6) Any other photos where there may be discontinuities to the structural form.

When possible, it is advised that measurements are provided within the photograph. For example, a section of truss can have its picture taken with a tape measure to provide a relative length which can then help verify the dimensions provided within the forms.

3.5. Truss analysis

This study presents an open-source systematic methodology for analyzing truss structures using the method of sections; a fundamental technique in structural analysis that efficiently resolves all the tension and compression loads acting on all members of a truss [39]. Trusses, extremely common in engineering and architectural domains for their load-bearing capabilities, are efficient structural members because of their ability to transfer loads dominantly through tensile and compressive stresses. By applying equilibrium principles to these sections, the internal tension and compression forces are resolved, and are then compared to the maximum tension and compression forces they can safely carry. This presented open-source tool not only offers a rigorous framework for truss analysis for PV installation using this method, but can also serve as a pragmatic toolkit for engineers and designers that wish to optimize the design of future structures for diverse applications.

3.6. Analysis assumptions

In the structural analysis of residential wooden trusses, several typical assumptions are made to assess the loading of members. Firstly, engineers typically assume that the truss members behave as pin-connected elements, neglecting any potential resistance to rotation at the joints [40]. This simplification allows for the application of equilibrium equations which provides for quick and efficient assessment of the internal forces within the truss. Additionally, it is common to simplify the problem such that all the loads are acting as on the joints of the top and bottom chords [40]. Although it is more accurate to assume the loads act as a uniform distributed load, the simplification of transferring to equivalent point loads allows for easy assessment of tensile and compressive forces, as bending effects can often be neglected. It is important to consult the solar panel racking manufacturer's technical specifications to ensure that the connections do not significantly damage the top chord of the truss, as improper installation can compromise structural integrity.

4. Economic and policy analysis

To quantify the benefit of adoption of this open-source tool discussed in section 3 three scenarios are considered: 1) plug-and-play PV, 2) DIY PV, and 3) professional installed systems residential systems. For each scenario, a sensitivity is run for the structural engineering estimates from $900 to $5,000 or more per rooftop [[29], [31], [32]]. It should be noted these costs do not scale with the size or the cost of the system, rather they are fixed based on the cost to analyze the structure of the roof.

First, the smallest system of relevant size would be a plug-and-play PV module with a microinverter, which meets all necessary standards and codes in the U.S. [41]. Such systems could have a potential market of over 57 GW of PV demand in U.S. [42]. Such systems would be installed by homeowners themselves incrementally one module at a time. Thus the initial system is assumed to be only 250W (4 modules per kW) and $1.25/W in the U.S. and a sensitivity is run up to 1kW, which is the max allowed on one circuit in the jurisdictions that allow it [42]. The total cost for the plug-and-play system in the smallest increment is $312.50.

The second option uses a do it yourself (DIY) method for mounting a small scale PV system of 1kW on a roof by the owner, which generally reduces the capital costs by about 50% or $1.50/W [43]. This is done because all labor costs are assumed to be zero if it is installed by the homeowner other than the final electric hookup by a conventional electrician. A sensitivity is run from 1kW up to 15kW.

A sensitivity analysis is run on a standard PV rooftop installation from 1kW to 15kW, which would encompass the vast majority of residential net metered systems [5]. For these systems the installed cost is assumed to be near the median of $3.00/W in both the U.S. and Canada. A simple case study is presented showing the impact for a typical homeowner targeting a 5kW PV system.

Finally, the demographics are considered of current PV ownership. It is well known that one of the most important factors in PV adoption for homeowners is income [44]. The higher the income the higher the solar adoption [[45], [46], [47]]. In the context of the fraction of the costs due to building code policy, the higher the income, the larger the house and load, and thus the larger the PV system. As PV system size increases the fixed costs associated with building code compliance are reduced as a fraction of the total system. This results in a cost penalty on the smaller systems, which lowers the financial return (or completely eliminates it), which again is a primary consideration in solar energy adoption [[48], [49]]. The ramifications of an upgrading of building code policy will be extrapolated to the impact on energy policy.

5. Results and implications

5.1. Eliminating redundant engineering costs

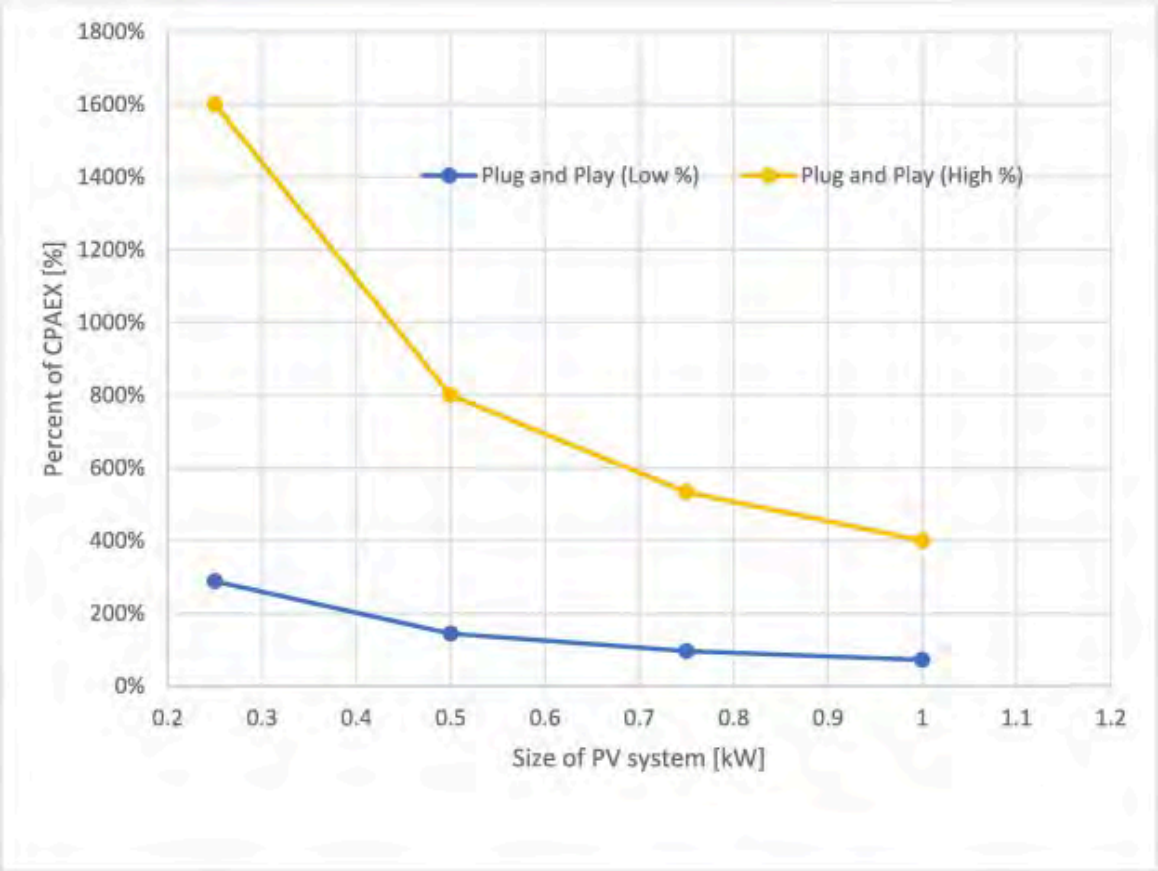
The open-source tool provided in this study can be used to bypass the need for professional engineer inspections while ensuring compliance with building codes. By providing a minimum of 5 photos along with the three forms to a local authority, the process of hiring a structural engineer to

bill their time to do this inspection is eliminated, thus saving both time and money in the installation process. The calculations generated by the program are accurate and reliable as seen in Appendix A, enabling users to make informed decisions about their solar panel installation. Additionally, the program's affordability (free) contributes to a significant reduction in overall installation costs.

Dwyer et al. explored the conservative nature of regulations and codes governing residential construction and associated structural system calculations [50]. This prominent source discusses the implications and considerations for residential rooftop solar panel installations, particularly regarding structural code requirements and the perceived need for robust structural support to manage additional loads such as uplift from PV solar installations. The claim that typical residential rooftops may be structurally inadequate to support the additional load from a PV solar installation is often based on overly conservative analyses. These analyses often simplify complex non-linear structures into basic determinate beams, ignoring the composite action of the entire roof structure and potentially resulting in an unnecessarily conservative view of structural adequacy [50]. This insight indicates that the additional uplift load on a rooftop with solar modules installed may have negligible effects on the structural capacity of the rooftop, as current engineering methods for calculating roof stresses could be oversimplifying and overstating the actual impact [50]. As a result, it is safe to determine that even with the simplifications used within the analysis of this open-source tool and in structural engineer's assessment, rooftops with slim margins of safety should not raise significant concerns.

5.2. Quantified cost savings

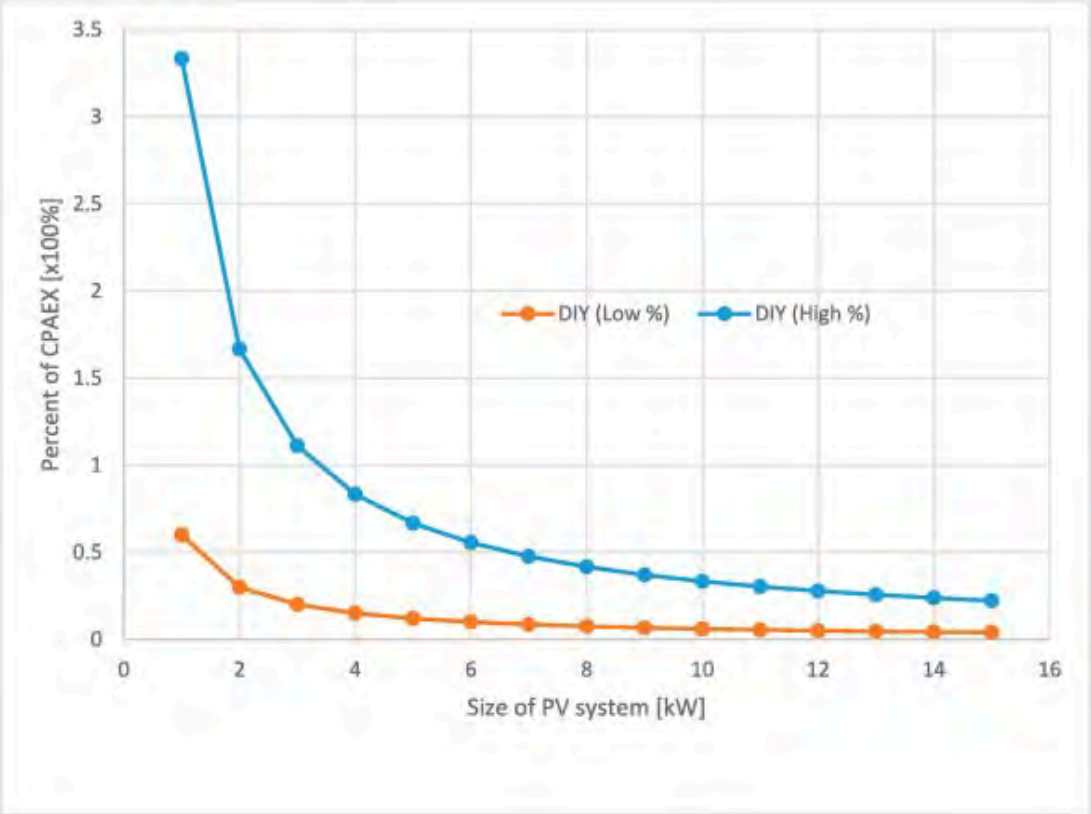
Considering soft costs still dominate a large portion of total PV costs, removing the engineering calculation and engineering inspection fees of a residential system has significant advantages. Typically, hiring a structural engineer to perform these identical tasks can be a considerable expense. According to MNA Quality Consulting, fees for structural engineer services in Canada range widely, with project-specific costs stretching from $300 to $5,000, and hourly rates falling between $100 and $230 [32]. HomeGuide also outlines the costs associated with hiring a structural engineer for residential projects, including house inspections and report fees which range from $350 to $900, and engineering design plans and drawings, which can cost between $500 and $3,000 [31]. As previously mentioned, engineering approval fees for PV systems in Canada can range from $900 (low case) to $5000 (high case) per installation based on the location and complexity of the installation. When these costs are eliminated, the savings in Canada are substantial as shown in Fig. 3, Fig. 4, Fig. 5 for the plug-and-play option, DIY, and professional installation, respectively.



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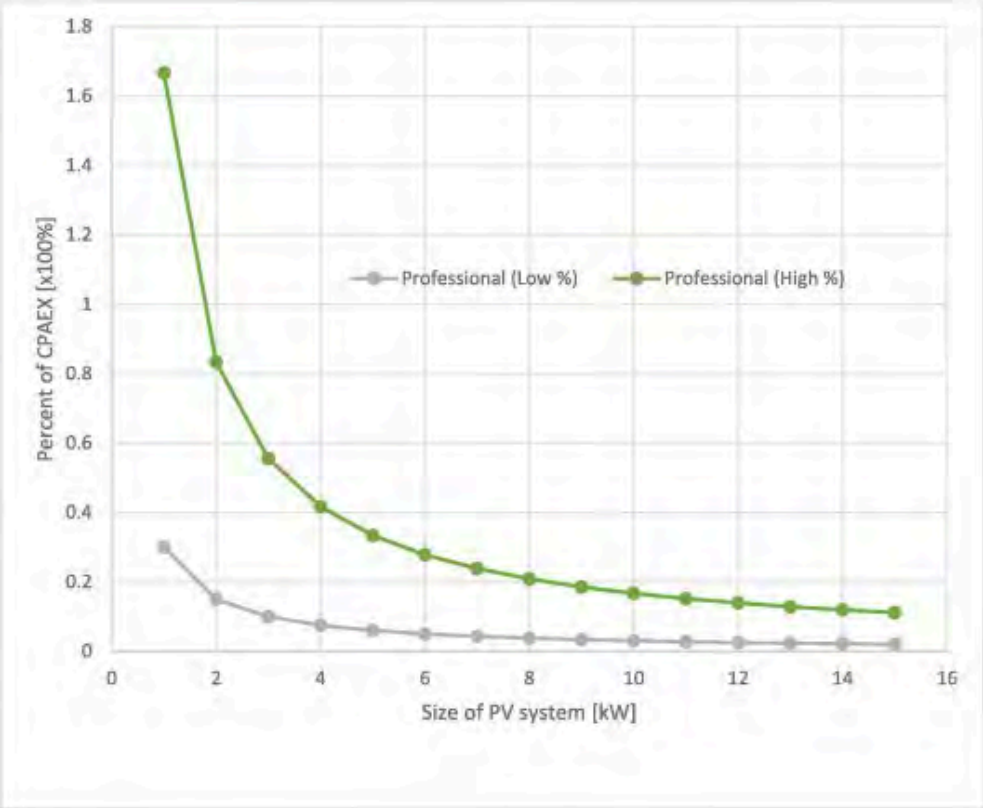
Fig. 3. Percent of CAPEX saved in plug-and-play PV systems by eliminating engineering charges for rooftop installation as a function of size of rooftop system in Canada.



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Fig. 4. Percent of CAPEX saved in DIY PV systems by eliminating engineering charges for rooftop installation as a function of size of rooftop system in Canada.



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Fig. 5. Percent of CAPEX saved in professional installations by eliminating engineering charges for rooftop installation as a function of size of rooftop system in Canada.

By comparing the results in Fig. 3, Fig. 4, Fig. 5, it is clear that the smaller and lower costs systems are the most profitable to apply the open-source tool for eliminating structural engineering costs. For the plug-and-play systems that are limited to only a kW for one panel (250W), the savings range from 288% to 1600%, while these numbers are reduced to 72% and 400% for the low and high cases, respectively.

For the DIY low cost estimate for engineering services eliminated is still 60% of the CAPEX costs at 1 kW but shrinks to 4% at 15 kW. Similarly, the high DIY cost savings runs from 333% at 1 kW down to 20% at 15 kW.

Lastly the cost savings for the professional installation are the smallest of the three case studies ranging from 30% to 167% at 1 kW and range from 2% to 11% for 15 kW. Thus, for all cases there are substantial savings in Canada.

Even in the much larger market of the U.S. this tool can be useful. Consider for example, the average cost for a 5 kW residential PV system is about $3.09/W [51]. A 5 kW system would have a total cost of $15,450, so adding the average of the engineering fees of about $3,000 would bring a typical residential PV system to $18,450 (the range would be $16,350 to $20,450). Effectively, the analysis

provided here indicates the open source tool can help reduce the total project capital cost by 20% (full range 5–25%).

Does a 20% discount matter economically to the typical homeowner? To demonstrate that answer to that question a short case study is presented for a below average household that would normally not be able to afford solar. If it is assumed the PV system would need to be financed with a 15year loan and that the house is located in a below average cost of electricity location and a below average solar location is selected: Michigan. If that 5kW PV system is located in Michigan, NREL PVWatts simulation [52] shows only an estimated 6,118 kWh/year generated and electricity in Michigan average 19 cents/kWh [53] or about $1,162/year. With the use of the open source tool provided in this manuscript the homeowners would have their system paid for in 13years while without it the simple payback time is extended 16years. As the payback time is extended beyond the loan term this system would simply not be installed without the open source tool because the homeowners could not afford the extra costs of the engineering fees (even though the system still provided a positive ROI). There are clearly savings when considering that the inspection is done by the homeowner or the solar installer rather than a professional engineer billing hours to conduct it. This makes PV systems more accessible to less affluent homeowners as the upfront cost is substantially reduced.

6. Limitations

There are several limitations to this approach.

6.1. Load effects on other structural elements

In considering the structural implications of installing PV systems on rooftops, it is important to acknowledge the limitations of the analysis. While the focus of this policy paper primarily revolves around the load effects on the trusses supporting the roof, it is essential to recognize that these loads ultimately transfer to other structural elements such as walls, lintel beams over windows, and the foundation. This study solely addresses the load-bearing capacity of the trusses and neglects the potential impacts on these additional structural elements. Depending on factors such as the size of walls, lintels, foundation, and the bearing capacity of the soil, the decision to neglect these effects may vary. Nevertheless, it is worth noting that the additional dead load of solar panels typically increases the total load on the trusses by approximately 10%. Given the redundant load-sharing members present in most residential structures, it can generally be assumed that the effects on other structural elements are negligible. Due diligence, however, should be exercised, particularly if concerns arise regarding the strength of lintels or other load-bearing components within the structure.

6.2. Truss simplicities

Furthermore, it is essential to recognize that the applicability of this open-source package is limited to relatively simple truss configurations, such as those demonstrated in the supporting material (e.g., Fink, Pratt, and King post trusses), commonly found in residential structures. For rooftops featuring complex custom-designed trusses or exhibiting irregularities in truss pattern and spacing, the accuracy of the analysis provided by the open-source package may be compromised or may be unusable. In such cases, consulting a structural engineer is essential to ensure the structural integrity and safety of the rooftop PV installation. There is also a need to expand this tool in the future to all roof types. Therefore, while this open-source tool offers a valuable tool for preliminary analysis and decision-making, its utility is limited in cases of more intricate structural configurations. While the current open-source package is unable to address custom-designed truss configurations, there is potential for future enhancements to broaden its applicability. The development of this tool from a spreadsheet to a full-blown free web-based application is an area of rich future work. Subsequent iterations of this open-source package can focus on incorporating functionalities that can accommodate a broader range of truss styles and configurations. By doing this, the package can become more versatile and applicable to a wider audience seeking to install PV systems on various types of roofs.

6.3. Warranties and liabilities

Additionally, it is important to recognize that utilizing this open-source package without consulting a structural engineer may lead to unintended consequences and potential liabilities for users. For instance, warranties on PV modules and roofing shingles may be voided if the installation does not meet manufacturer specifications or industry standards. Moreover, the users may assume liabilities for defects in the home's structure, such as roof leaks or truss failures, resulting from inadequate structural analysis and design from the misuse of this open-source package. In the event of such issues, the responsibility for repairs or damages may fall squarely on the users, thus potentially leading to financial burdens and legal implications.

These risks can be mitigated, however, through thorough due diligence and honest assessment of the structural integrity of the rooftop PV installation. This practice can perhaps most effectively be realized by PV installers adding a non-engineer structural analysis. As these systems are focused on the most common types of roof tops, installers would already have experience with ‘rubber stamp’ engineering occurring when the structural engineer does not even need to do the analysis again as they already have templates similar to the tool developed here to determine adequacy of a roof to PV installation. By conducting comprehensive inspections and ensuring the input data is accurate, users can minimize the likelihood of defects and associated liabilities.

6.4. Calibration to Canadian codes

The development of this open-source program has been meticulously calibrated to align with the National Building Code of Canada (NBCC) [29] and CSA O.86 Engineering Design in Wood [30], ensuring that it adheres to Canada’s stringent requirements for structural integrity and safety in

solar panel rooftop installations. By integrating these codes, the program provides a reliable assessment of rooftop solar readiness that could be ported to other jurisdictions with lesser requirements (e.g., the potential heavy snow loads calculated here in Canada). It is, however, acknowledged that Canada's diverse and multifaceted legal and regulatory landscape represents just one of many national contexts in which such a tool could prove beneficial. Recognizing this, future enhancements to the open-source tool can aim to incorporate a wider array of international building codes and standards. This evolution requires extensive collaboration with those with familiarity with structural principles and code compliance to adapt the tool for global use. This work aids in expanding the tool's applicability and ensures that solar panel installations worldwide can proceed with confidence in their compliance with local codes and regulations.

7. Policy

The results of this study indicate there is a clear economic advantage to using the provide open-source tool for the three types of trusses used here. Using the tool reduces costs and would presumably accelerate PV adoption based on former studies [[48], [49]]. The results of deploying this policy would be expected to have the largest impact on less-affluent potential solar adopters because of the greater percentage of effective discount on the capital costs of systems compared to the status quo. This could help shift the demographics of solar adoption away from the current clustering on the affluent [48]. There are far greater numbers of less affluent people [54] and the adoption of this open source tool would effectively decrease the total cost of PV installations and thus this would be expected to greatly increase the market for PV. As PV is a a long term investment offering solid returns (which are not taxed) this could also go towards reducing wealth disparities [54], although future work is needed in these areas. There are, however, s two major energy policy potentials as deploying the tool in building code policy effectively (although indirectly) impacts energy policy.

First, as this analysis was developed for Canada, other countries could benefit from the free deployment of derivative tools in other legal jurisdictions. This could be funded by 1) government to spur renewable energy growth and cut emissions, 2) a non-profit organization (NPO) representing solar companies (e.g.. the Solar Energy Industry Association) or an environmental NPO who would do so to help protect the environment from carbon emissions, 3) a large developer of PV systems to expand their market (or cut their costs if they pay for the existing structural engineer) or 4) the local, regional or central government. In all cases, not only would potential small PV systems benefit but the governments would also benefit from the increased economic activity of the PV systems. Regardless of funder, the relatively modest investment in the development of such a tool is recouped even by a handful of residential systems using it.

Second, policies could be enacted that would increase the viability and sustainably of the tool. This would involve future work in the development of the other types of commercial trusses. In the current state of this open-source tool, feedback on how to increase the capacity of the trusses is

unavailable, and thus, these enhancements require consultation from a structural engineer. Future work should be conducted such that when a truss is deemed ineligible to carry the additional load of a PV system, solutions such as adding vertical compressive struts to the truss should be considered. These vertical struts, typically connected between the top and bottom chords, allow for smoother load transfer, and reduce the unsupported length of the compressive top chord, thus significantly increasing the overall capacity, allowing for virtually any rooftop to be eligible for PV installation.

8. Conclusions

From the results of this study, it can be concluded that the introduction of this open-source tool for analyzing and inspecting roofs for solar panel installation presents a significant cost-saving opportunity for Canadian rooftop PV owners. In Canada, the results show the percent savings ranges from 2% for low-cost professional systems up to 1,600% for the plug and play high cost estimate. In addition, the analysis provided here indicates the open source tool can help reduce the total PV project cost by 5–25% for average residential PV systems. A case study was presented in the US that showed the cost savings for implementing the policy and open source tool provided in this article were enough to make a below average electricity cost and solar flux location accessible to PV adoption for poorer households. Without the tool the 5 kW system would simply not be affordable for a low-income family. Considering these figures, the adoption of an open-source tool could potentially save rooftop PV owners up to several thousand dollars and potentially cut the cost of a small-scale PV system in half. These savings stem from the elimination of the need to hire a structural engineer for initial assessments, inspections, and the drafting of compliance reports regarding the structural integrity of the roof for solar panel installations. This approach simplifies access to solar energy by reducing upfront costs thus accelerating the transition towards sustainable energy solutions by streamlining the solar panel installation process.

In summary, this open-source package addresses the challenges associated with professional engineer inspections for solar panel installations on rooftops. The first step to allow for widespread utilization of this open-source package is recognition in the National Building Code of Canada that assessment using this framework is not required by a structural engineer. Part 9 of the code highlights the many structural decisions (such as sizing joists for floors) that can be made on residential homes without the need to hold a structural engineering stamp and seal [33]. With greater recognition of this open-source framework, PV installation can safely be introduced into Part 9 of the NBCC under typical conditions, thus providing regulated guidance for anyone who wishes to install PV on a rooftop. Moreover, the National Research Council of Canada offers open-source software such as wind design load calculators, that are designed to aid engineers and architects in selecting cladding for building rooftops [37]. A similar framework could be implemented from the national government of Canada as well as for other national governments for this open-source package to allow homeowners to seamlessly add PV to their rooftop. In addition, governments could then provide an enhanced program including some basic training to aid home

builders so that newly proposed residential houses can readily have PV installed during the initial stages of construction. In addition, a comprehensive program would provide training for using the open source tool for PV installers. The proposed open-source program provides an efficient and cost-effective solution by offering accurate structural engineering calculations while ensuring compliance with building codes. The accessibility and affordability of rooftop PV systems are significantly improved from these relatively minor and low-cost policy changes because of the elimination of redundant engineering, therefore marking a substantial step towards a more sustainable and widespread adoption of solar energy. Most importantly this policy change would be expected to have the largest positive impact on low-income individuals as it would make an economic return viable on small rooftop PV systems. Finaly, future work should investigate other policies that could be opportunities to form of indirect energy policy that benefits marginalized groups and overall decarbonization of the energy system.

CRediT authorship contribution statement

Nicholas Vandewetering: Writing – review & editing. **Joshua M. Pearce:** Writing – review & editing.

Declaration of Competing Interest

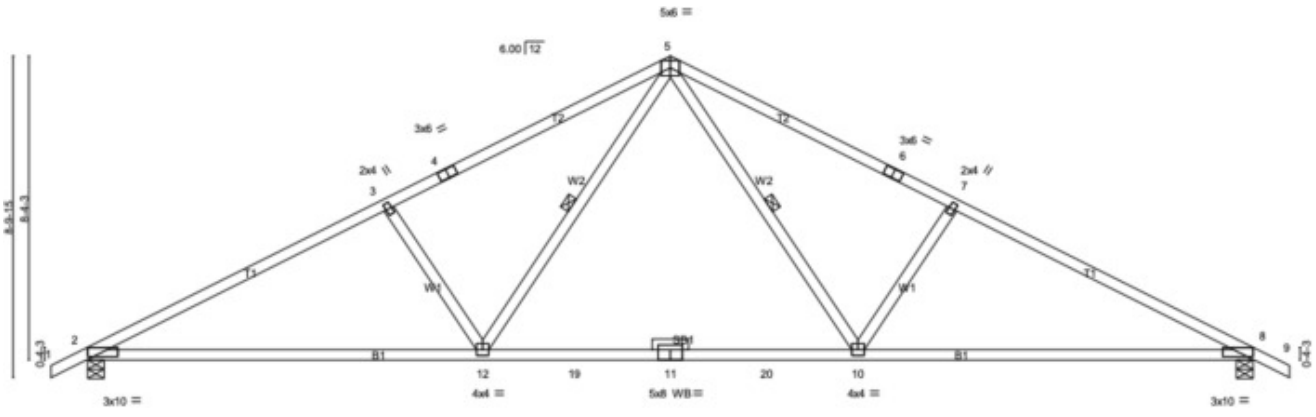
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

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Appendix A.

A typical fink truss is assessed as illustrated in Figure A1.



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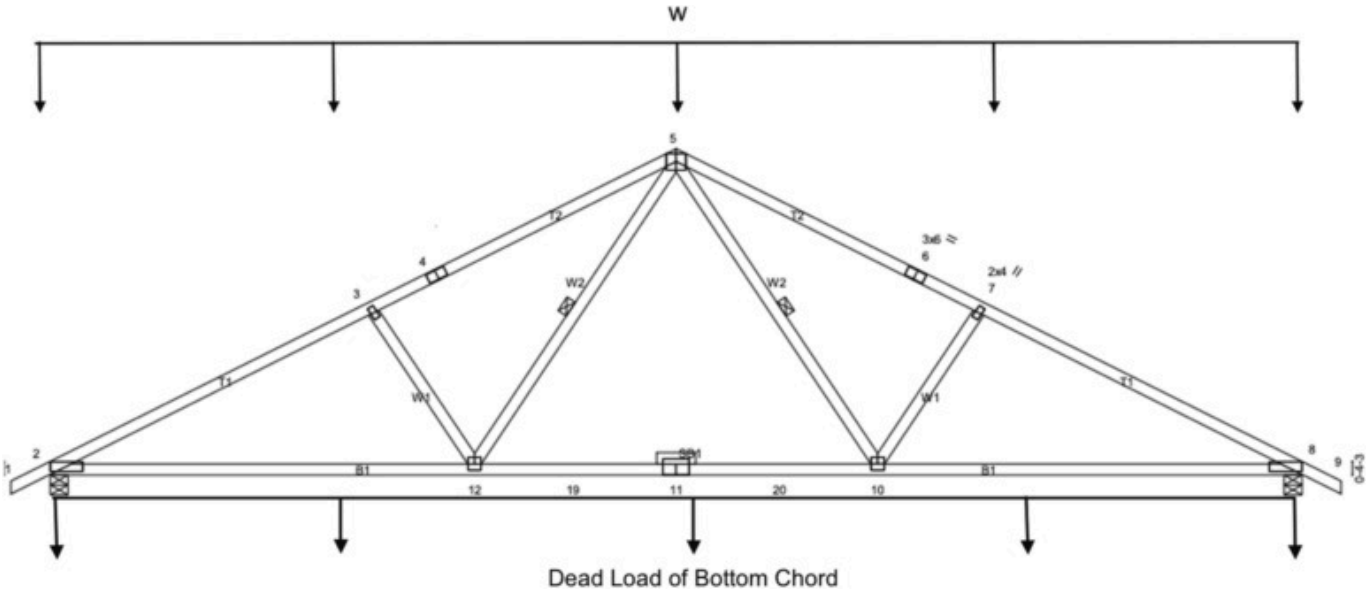
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Fig. A1. Elevation view of a typical fink truss.

The total design load calculated, given as a kPa, can then be converted into a uniform distributed load acting along the top chord by multiplying by the truss spacing, using Equation A(1) below. The same is done for the bottom chord, where just the factored dead load is applied.

$$w = DesignLoad * TrussSpacing \tag{A1}$$

The truss loading can now be visualized as seen in Figure A2.



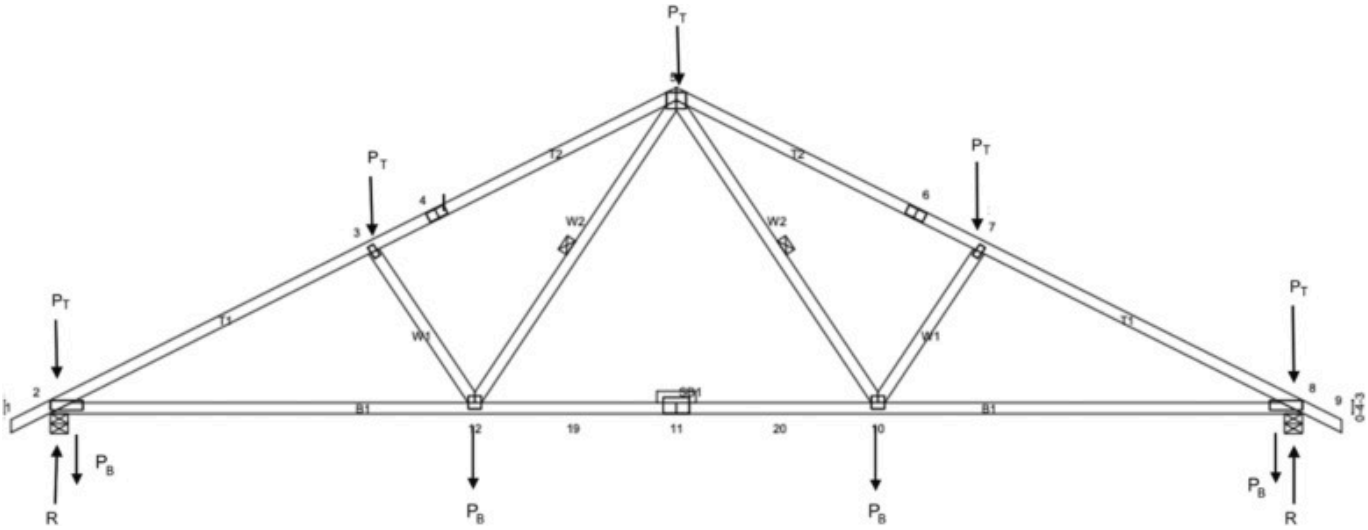
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Fig. A2. Free Body Diagram of a Typical Truss with a Uniform Distributed Load.

The uniform distributed load can then be converted into equivalent point loads by multiplying this load by the length of the truss, and then dividing by the total number of joints along the chord. The

loading is now provided as shown in Figure A3.



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Fig. A3. Free Body Diagram of a Typical Truss with Point Loads.

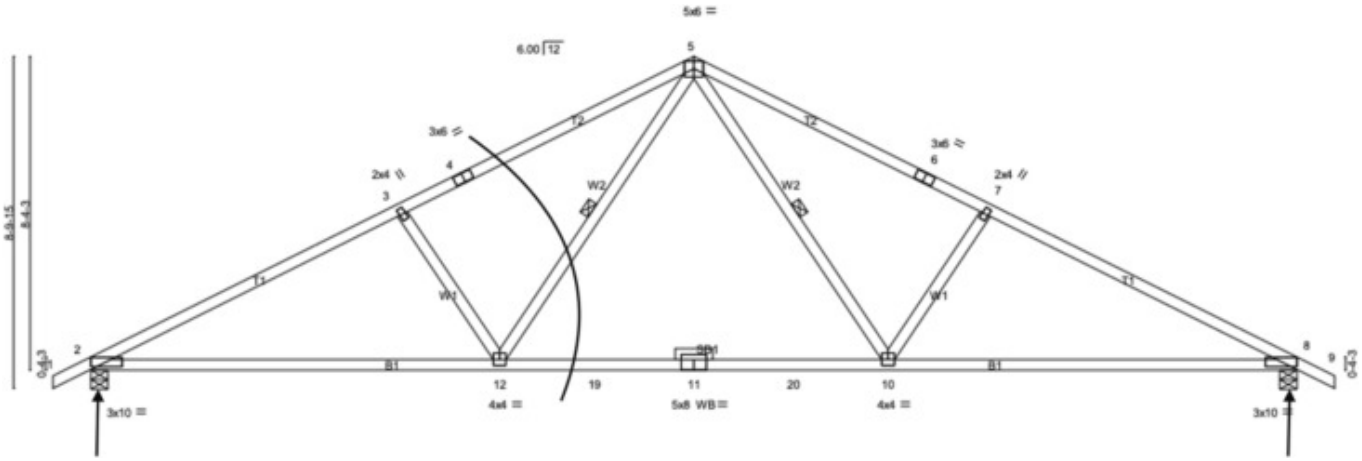
Determining the reactions at each truss support point is crucial for assessing the load-bearing capacity of the system. To resolve these reactions, engineers commonly use a straightforward equation: the sum of the external forces acting on the truss divided by two, which is provided in Equation A(2). This equation below provides a concise and practical method for determining R, the truss end reactions.

$$\boldsymbol{R} = \frac{\sum \boldsymbol{P}}{\mathbf{2}} \tag{A2}$$

For the case of the example truss, each reaction takes $2.5P_T + 2P_B$ worth of load.

The first step in the method of sections involves ‘cutting’ a cross-section of the truss. This cut is used to determine the internal forces in the members. Refer to Figure A4 for a cut along the top

chord, middle web, and bottom chord.



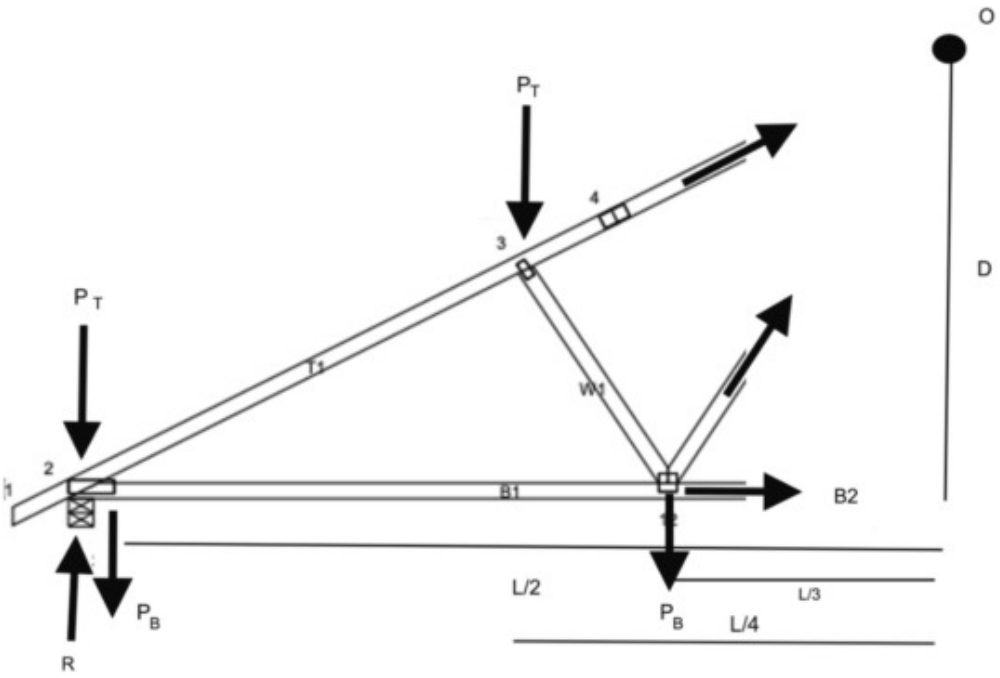
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Fig. A4. A Cut Section of the Truss to Assess Internal Loads using the Method of Sections.

Once this cut is made, one of the sections (usually the smaller section) is selected to analyze. In this example, point O, as shown in Figure A5 is selected because the top chord and web's internal forces point towards it, leaving the bottom chord's internal force to be pointing away from it, thus inducing a moment, a force acting at a distance, about point O. The internal force in the 2nd bottom chord, B2, can be resolved by using the equilibrium equation, Equation A3a. All of the moments acting about point O are assessed, equal to 0 in Equation A3b, and then B2 is solved in Equation A3c. It is advised to first assume that all the forces are acting in tension, that is, away from the cut. Then, when the result is negative, it confirms that the member is in compression rather than tension. Additionally, it is assumed that counterclockwise moments are positive. Both assumptions are

interchangeable as long as the analysis remains consistent.



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Fig. A5. Free Body Diagram of Cut Section to Assess Tension in the Bottom Chord, B2.

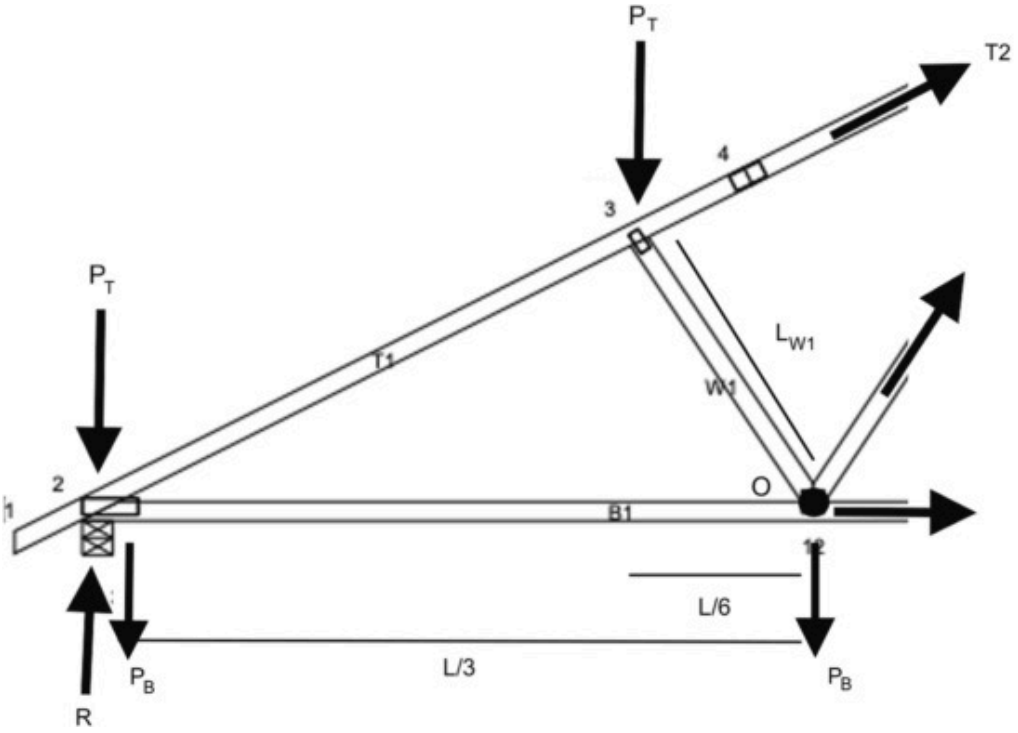
$$\sum M_O = 0 \tag{A3a}$$

$$P_T\left(\frac{L}{2}\right)+P_T\left(\frac{L}{4}\right)+P_B\left(\frac{L}{3}\right)+P_B\left(\frac{L}{2}\right)+B2\,(D) - R\left(\frac{L}{2}\right)= 0 \tag{A3b}$$

$$B2 = \frac{R\left(\frac{L}{2}\right)-P_B\left(\frac{5L}{6}\right)-P_T\left(\frac{3L}{4}\right)}{D} \tag{A3c}$$

The next Point O is chosen to be at the joint in the bottom chord, since isolated the internal force in the top chord, T2 as illustrated in Figure A6. The internal force is solved and is provided in Equation A4 a, b, and c. The length of the 1st web, L_{W1}, can be found using trigonometry given the slope of

the roof, or by measuring it upon inspection.



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Fig. A6. Free Body Diagram of Cut Section to Assess the Internal Force in the Top Chord, T2.

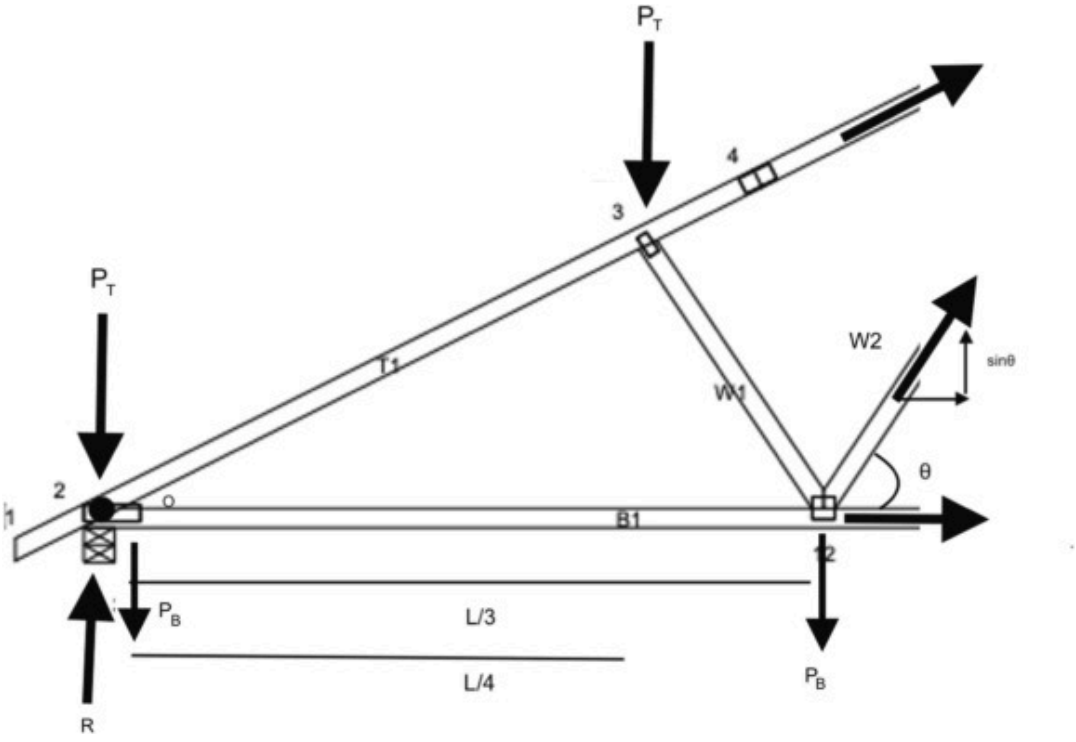
$$\sum M_O = 0 \tag{A4a}$$

$$P_T\left(\frac{L}{3}\right)+P_T\left(\frac{L}{6}\right)+P_B\left(\frac{L}{3}\right)+T2L_{W1} + -R\left(\frac{L}{3}\right)= 0 \tag{A4b}$$

$$T2 = \frac{R\left(\frac{L}{3}\right)-P_T\left(\frac{L}{2}\right)-P_B\left(\frac{L}{3}\right)}{L_{W1}} \tag{A4c}$$

Finally, Point O is then taken at the reaction, where both the top and bottom chord forces act along it, and the force within the web is isolated. This internal force is broken up into a vertical and horizontal component for simplicity. When assessing the web force at the joint with the bottom chord, the horizontal component acts along the line of point O, so only the vertical component induces a moment about point O. The equilibrium equation is applied and the solution for the web

force is given in Equation A5. This is illustrated in Figure A7. The vertical component.



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Fig. A7. Free Body Diagram of Cut Section to Assess Tension in the Web, W2.

$$\sum M_O = 0 \tag{A5a}$$

$$W2 sin\theta\left(\frac{L}{3}\right) - P_T\left(\frac{L}{4}\right) - P_B\left(\frac{L}{3}\right) = 0 \tag{A5b}$$

This process is continued to resolve each member. It should be noted that when assuming the loading on the truss is symmetric, the other side of the truss does not need to be assessed because it will be identical to the first side. This is thanks to the simplifying assumption that the PV load spans the entire truss. Cuts are continued to be taken until each member on one side of the truss is resolved.

For the example truss shown above, a typical truss spacing of 24″ or 600mm, and a truss span of 10m is tested. The loads derived for London Ontario are used for the input. The pitch, or slope of the roof, is assumed to be 4:12, which corresponds to 18 degrees. A summary of all the load acting on each critical member is provided in Table A1.

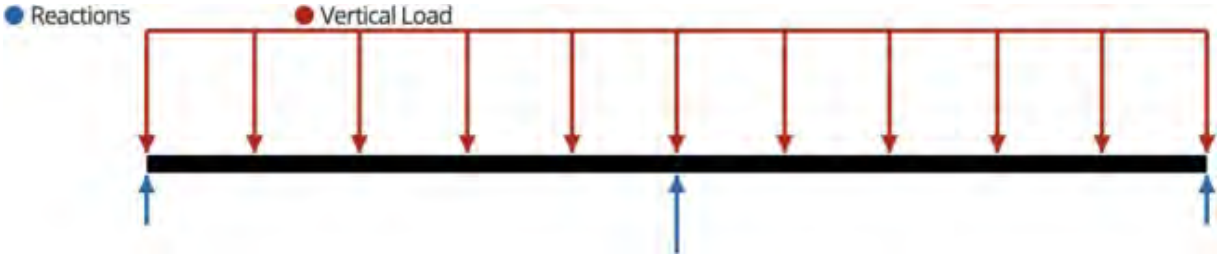
Table A1. Summary of the maximum internal forces acting on critical members of the fink truss.

Member	Maximum Force [kN]
Top Chord – Compression	19.22

Member	Maximum Force [kN]
Bottom Chord – Tension	21.32
Web – Compression	2.91
Web – Tension	3.61

2.1.1. Bending plus compression

It should be noted that the simplification of converting the uniform distributed load into point loads at the joints neglects the effects of flexural bending stress in the top chord between the joints. After the axial forces are resolved, a bending check can be conducted by treating the top chord as a continuous beam as shown in Figure A8.



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Fig. A8. Free body diagram of the top chord serving as a bending member.

As this beam is considered indeterminate, meaning that it is not possible to solve with fundamental static methods. It is recommended that the beam is programmed into ClearCalcs, an open-source structural analysis software that produces the shear, bending, and deflection profiles of beams under simple loading conditions [55].

Once the maximum bending stress is resolved, the capacity of the top chord is found by using Equation A(6).

$$\frac{\frac{C}{A}}{fc^*} + \frac{\frac{M}{S}}{fb^*} \leq 1 \tag{A6}$$

where A is the cross-sectional area, S is the section modulus of the cross-section, fc* is the maximum compressive stress capacity, and fb* is the maximum bending stress capacity. These values can be calculated by following the material capacity procedure as outlined in [36]. For relatively short spans, or for trusses with many joints along the top chord, the bending stress may be negligible and so, this check can be avoided.

2.1.2. Buckling of compression members

It is important to assess the compression members to ensure they do not fail due to buckling instability. The buckling capacity of a member can be determined using the Euler's buckling equation provided in Equation A(7).

$$C_{Buckling} = \frac{\pi^2 EI}{L^2} \quad \text{(A7)}$$

Where $C_{Buckling}$ is the critical buckling load, E is Young's modulus of elasticity of the species of wood used, I is the moment of inertia of the member's cross-section, and L is the unbraced length of the member.

In the context of truss analysis for rooftop PV installations, it is important to note that the top chords are laterally supported throughout their entire length on their weak axis due to the presence of plywood sheathing. Consequently, only the strong axis buckling needs to be assessed. The moment of inertia upon the member's weak axis can be calculated using Equation A(8):

$$I = \frac{1}{12} bh^3 \quad \text{(A8)}$$

where b is the width and h is the height of the member's cross-section.

In addition, it should be noted that that in some truss configurations, lateral braces may be installed at the midpoint of certain compression webs to mitigate buckling instability. These braces provide additional lateral support, reducing the effective length of the compression members. If such members with lateral braces exist within the truss being analyzed, the unbraced length used in the Euler's buckling equation can be divided by 2 to account for this reduced length. If no lateral braces are present, however, the full length of the member must be considered in the analysis.

If the buckling capacity is less than the compression capacity derived in the strength of wood in CSA O.86 [30], then this value will be used in when comparing to the maximum internal force.

Finally, the capacity over demand ratio is solved by simply dividing the derived strength of the member by the maximum load effect. Table A2 provides a summary of the ratios for each of these members. The top and bottom chords consider the combined loading of both the axial and flexural effects in this assessment.

Table A2. Summary of capacity over demand for critical members in the fink truss.

Member	Capacity over Demand
Top Chord – Compression	1.54
Bottom Chord – Tension	1.54
Web – Compression	12.31
Web – Tension	9.26

Since all of these values are above 1.00, they will not fail under these design loads, and thus they are deemed safe to carry the additional PV load.

Recommended articles

References

[1] J.M. Pearce
Photovoltaics — a path to sustainable futures
Futures, 34 (2002), pp. 663-674, 10.1016/S0016-3287(02)00008-3 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[2] T.M. Letcher, Why Solar Energy?, in: A Comprehensive Guide to Solar Energy Systems. Elsevier, 2018, pp. 3–16.
Google Scholar ↗

[3] C.J., Chen, Physics of solar energy. John Wiley & Sons. 2011, URL https://www.columbia.edu/~jcc2161/documents/Solar_Energy.pdf (accessed 3.31.24).
Google Scholar ↗

[4] C.B., Evans, Solar is now 'cheapest electricity in history', confirms IEA [WWW Document]. Carbon Brief. 2020, URL https://www.carbonbrief.org/solar-is-now-cheapest-electricity-in-history-confirms-iea/ (accessed 4.19.24).
Google Scholar ↗

[5] National Academies of Sciences, Engineering, and Medicine, 2023. The role of net metering in the evolving electricity system.
Google Scholar ↗

[6] S. Baker-Branstetter
Distributed renewable generation: the trifecta of energy solutions to curb carbon emissions, reduce pollutants, and empower ratepayers
accessed 3.31.24
Vill Envtl LJ, 22 (2011), p. 1
https://digitalcommons.law.villanova.edu/elj/vol22/iss1/1/ ↗
Google Scholar ↗

[7] L.L. Davies, S. Carley
Emerging shadows in national solar policy? Nevada's net metering transition in context
Electr. J., 30 (2017), pp. 33-42, 10.1016/j.tej.2016.10.010 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[8] B. Del Chiaro, R. Gibson
Government's Role in Creating Avibrant Solar Power Market in California
Gold. Gate UL Rev, 36 (2006), p. 347
Google Scholar ↗

[9] K.S. Hayibo, J.M. Pearce
A review of the value of solar methodology with a case study of the U.S
VOS. Renew. Sustain. Energy Rev., 137 (2021), Article 110599, 10.1016/j.rser.2020.110599 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[10] K. Branker, M. Pathak, J.M. Pearce
A review of solar photovoltaic levelized cost of electricity
Renew. Sustain. Energy Rev., 15 (2011), pp. 4470-4482
View PDF View article View in Scopus ↗ Google Scholar ↗

[11] G. Barbose, A.J. Satchwell
Benefits and costs of a utility-ownership business model for residential rooftop solar photovoltaics
Nat. Energy, 5 (2020), pp. 750-758, 10.1038/s41560-020-0673-y ↗
View in Scopus ↗ Google Scholar ↗

[12] V. Bertsch, J. Geldermann, T. Lühn
What drives the profitability of household PV investments, self-consumption and self-sufficiency? Appl
Energy, 204 (2017), pp. 1-15, 10.1016/j.apenergy.2017.06.055 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[13] X. Han, J. Garrison, G. Hug
Techno-economic analysis of PV-battery systems in Switzerland
Renew. Sustain. Energy Rev., 158 (2022), Article 112028, 10.1016/j.rser.2021.112028 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[14] E. O'Shaughnessy, G. Barbose, R. Wiser, S. Forrester, N. Darghouth
The impact of policies and business models on income equity in rooftop solar adoption
Nat. Energy, 6 (2021), pp. 84-91, 10.1038/s41560-020-00724-2 ↗
View in Scopus ↗ Google Scholar ↗

[15] K.R. Khalilpour, A. Vassallo
Technoeconomic parametric analysis of PV-battery systems
Renew. Energy, 97 (2016), pp. 757-768, 10.1016/j.renene.2016.06.010 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[16] A. Stephan, B. Battke, M.D. Beuse, J.H. Clausdeinken, T.S. Schmidt
Limiting the public cost of stationary battery deployment by combining applications
Nat. Energy, 1 (2016), p. 16079, 10.1038/nenergy.2016.79 ↗
View in Scopus ↗ Google Scholar ↗

[17] F. Tan
Solar costs to fall further, powering global demand - Irena
Reuters. (2017)
Google Scholar ↗

[18] Aurora Solar, 2018. How Net Metering Is Evolving: Three Changes You Need to Know [WWW Document]. Aurora Sol. URL https://aurorasolar.com/blog/how-net-metering-is-evolving-three-changes-you-need-to-know/ (accessed 4.19.24).
Google Scholar ↗

[19] Energysage, 2023. NEM 3.0 in California: What You Need to Know [WWW Document]. EnergySage. URL https://www.energysage.com/blog/net-metering-3-0/ (accessed 4.14.24).
Google Scholar ↗

[20] H. Liu, D. Azuatalam, A.C. Chapman, G. Verbič
Techno-economic feasibility assessment of grid-defection
Int. J. Electr. Power Energy Syst., 109 (2019), pp. 403-412
View PDF View article View in Scopus ↗ Google Scholar ↗

[21] K. Say, M. John, R. Dargaville, R.T. Wills
The coming disruption: the movement towards the customer renewable energy transition
Energy Policy, 123 (2018), pp. 737-748, 10.1016/j.enpol.2018.09.026 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[22] B.K. Sovacool
Distributed Generation (DG) and the American Electric Utility System: what is stopping it?
J. Energy Resour. Technol., 130 (2008), 10.1115/1.2824296 ↗
Google Scholar ↗

[23] M. Richter
Utilities' business models for renewable energy: a review
Renew. Sustain. Energy Rev., 16 (2012), pp. 2483-2493, 10.1016/j.rser.2012.01.072 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[24] C. Eid, J. Reneses Guillén, P. Frías Marín, R. Hakvoort

The economic effect of electricity net-metering with solar PV: consequences for network cost recovery, cross subsidies and policy objectives

Energy Policy, 75 (2014), pp. 244-254, 10.1016/j.enpol.2014.09.011 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

[25] E. Prehoda, J.M. Pearce, C. Schelly

Policies to overcome barriers for renewable energy distributed generation: a case study of utility structure and regulatory regimes in Michigan

Energies, 12 (2019), p. 674, 10.3390/en12040674 ↗

View in Scopus ↗ Google Scholar ↗

[26] R. Seguin, J. Woyak, D. Costyk, J. Hambrick, B. Mather, High-Penetration PV Integration Handbook for Distribution Engineers (No. NREL/TP-5D00-63114). National Renewable Energy Lab. (NREL), Golden, CO (United States), 2016, Doi: 10.2172/1235905.

Google Scholar ↗

[27] O. Gandhi, D.S. Kumar, C.D. Rodríguez-Gallegos, D. Srinivasan, Review of power system impacts at high PV penetration Part I: Factors limiting PV penetration. Sol. Energy, Special Issue on Grid Integration, 2020, 210, 181–201. Doi: 10.1016/j.solener.2020.06.097.

Google Scholar ↗

[28] S.A. Aleem, S.M.S. Hussain, T.S. Ustun

A review of strategies to increase PV penetration level in smart grids

Energies, 13 (2020), p. 636, 10.3390/en13030636 (accessed 3.31.24) ↗

View in Scopus ↗ Google Scholar ↗

[29] Canada, G. of C.N.R.C., National Building Code of Canada: 2020 - NRC Publications Archive. 2024. URL https://nrc-publications.canada.ca/eng/view/object/?id=515340b5-f4e0-4798-be69-692e4ec423e8 (accessed 3.31.24).

Google Scholar ↗

[30] Canadian Wood Council, 2017. CSA O86 Engineering design in wood - The Canadian Wood Council [WWW Document]. Can. Wood Counc. - CWC. URL https://cwc.ca/en/how-to-build-with-wood/codes-standards/wood-standards/csa-o86-engineering-design-in-wood/ (accessed 3.31.24).

Google Scholar ↗

[31] Homeguide, 2023. 2024 Structural Engineer Costs | Inspection, Construction & Design Fees [WWW Document]. HomeGuide. URL https://homeguide.com/costs/structural-engineer-cost (accessed 3.31.24).

Google Scholar ↗

[32] Average Costs for Structural Engineering Services in Canada [2023] | MNA Quality Consulting [WWW Document], 2023 URL https://mnaquality.com/blog/average-costs-for-structural-engineering-services-in-canada (accessed 3.31.24).

Google Scholar ↗

[33] P.Eng Stamped Structural Roof Assessment - Structural Roof Load Assessment | Solar Roof Installation Permitting Service [WWW Document], 2024, Sol. Power Store Can. URL https://solarpowerstore.ca/products/p-eng-stamped-structural-roof-assessment (accessed 1.4.24).

Google Scholar ↗

[34] Renovationfind, 2020. Solar Panel Cost in Canada | (Price Guide and Calculator) [WWW Document]. Blog Renov. Find. URL https://blog.renovationfind.com/solar-panel-cost-in-canada/ (accessed 4.14.24).

Google Scholar ↗

[35] US Department of Energy, 2023. Permitting and Inspection for Rooftop Solar [WWW Document]. Energy.gov. URL https://www.energy.gov/eere/solar/permitting-and-inspection-rooftop-solar (accessed 4.13.24).

Google Scholar ↗

[36] Vandewetering et al. 2022. Designs, Impacts of Location on Designs and Economics of DIY Low-Cost Fixed-Tilt Open Source Wood Solar Photovoltaic Racking, MDPI Designs, URL https://www.mdpi.com/2411-9660/6/3/41 (accessed 3.31.24).

Google Scholar ↗

[37] Canada, G. of C.N.R.C., Licence Agreement for use of Wind load calculators for roof cladding and vegetated roof assembly | Wind load calculator for roof cladding and vegetated roof assembly | National Research Council Canada [WWW Document]. URL https://nrc.canada.ca/en/research-development/products-services/software-applications/wind-load-calculators-roof-cladding-vegetated-roof-assembly/app/agreement.html (accessed 4.13.24), 2020.

Google Scholar ↗

[38] Canmet Energy, 2019 Photovoltaic Ready Guidelines. URL https://natural-resources.canada.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/17-259_Photovoltaic-EN_accessible.pdf (accessed 3.31.24).

Google Scholar ↗

[39] 5.5: Method of Sections, 2021. [WWW Document]. Eng. Libr. URL https://eng.libretexts.org/Bookshelves/Mechanical_Engineering/Mechanics_Map_(Moore_et_al.)/05%3A_Engineering_Structures/5.05%3A_Method_of_Sections (accessed 4.2.24).

Google Scholar ↗

[40] Engineering Libretexts, 2020. 5.4: Assumptions in Truss Analysis [WWW Document]. Eng. Libr. URL https://eng.libretexts.org/Bookshelves/Mechanical_Engineering/Introduction_to_Aerospace_Structures_and_Materials_(Alderliesten)/02%3A_Analysis_of_Statically_Determinate_Structures/05%3A_Internal_Forces_in_Plane_Trusses/5.04%3A_Assumptions_in_Truss_Analysis (accessed 4.1.24).

Google Scholar ↗

[41] A.S. Mundada, Y. Nilsiam, J.M. Pearce
A review of technical requirements for plug-and-play solar photovoltaic microinverter systems in the United States
Sol. Energy, 135 (2016), pp. 455-470, 10.1016/j.solener.2016.06.002 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[42] A.S. Mundada, E.W. Prehoda, J.M. Pearce
U.S. market for solar photovoltaic plug-and-play systems
Renew. Energy, 103 (2017), pp. 255-264, 10.1016/j.renene.2016.11.034 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[43] L. Grafman, J.M. Pearce, P. Droz, H. Louie
To Catch the Sun: Inspiring stories of communities coming together to harness their own solar energy, and how you can do it too!
Humboldt State University Press, Arcata (2021)
Google Scholar ↗

[44] G.L. Barbose, S. Forrester, E. O'Shaughnessy, N.R. Darghouth, Residential Solar-Adopter Income and Demographic Trends, 2022 Update.
Google Scholar ↗

[45] T. Islam, N. Meade The impact of attribute preferences on adoption timing: The case of photo-voltaic (PV) solar cells for household electricity generation. Energy Policy, Special section: Long Run Transitions to Sustainable Economic Structures in the European Union and Beyond, 2013, 55, 521–530. Doi: 10.1016/j.enpol.2012.12.041.
Google Scholar ↗

[46] L. Legault, S. Bird, M.D. Heintzelman
Pro-environmental, prosocial, pro-self, or does it depend? A more nuanced understanding of the motivations underlying residential solar panel adoption
Energy Res. Soc. Sci., 111 (2024), Article 103481, 10.1016/j.erss.2024.103481 ↗
View PDF View article View in Scopus ↗ Google Scholar ↗

[47] B. Lin, S. Kaewkhunok

The role of socio-Culture in the solar power adoption: the inability to reach government policies of marginalized groups

Renew. Sustain. Energy Rev., 144 (2021), Article 111035, 10.1016/j.rser.2021.111035 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

[48] M. Alipour, H. Salim, R.A. Stewart, O. Sahin

Predictors, taxonomy of predictors, and correlations of predictors with the decision behaviour of residential solar photovoltaics adoption: a review

Renew. Sustain. Energy Rev., 123 (2020), Article 109749, 10.1016/j.rser.2020.109749 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

[49] E. Sardianou, P. Genoudi

Which factors affect the willingness of consumers to adopt renewable energies?

Renew Energy, 57 (2013), pp. 1-4, 10.1016/j.renene.2013.01.031 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

[50] S.F. Dwyer, B.P. Dwyer, A. Sanchez, Structural Code Considerations for Solar Rooftop Installations. (No. SAND2014-20601). Sandia National Lab. (SNL-NM), Albuquerque, NM (United States). 2014, Doi: 10.2172/1166692.

Google Scholar ↗

[51] D. Chung, C. Davidson, R. Fu, K. Ardani, R. Margolis, U.S. Photovoltaic Prices and Cost Breakdowns. Q1 2015 Benchmarks for Residential, Commercial, and Utility-Scale Systems, 2015. (No. NREL/TP--6A20-64746, 1225303). Doi: 10.2172/1225303.

Google Scholar ↗

[52] NREL

PVWatts Calculator [WWW Document]

accessed 10.6.24

https://pvwatts.nrel.gov/pvwatts.php ↗ (2024)

Google Scholar ↗

[53] EnergySage, 2024. Electricity Cost in Michigan: 2024 Electric Rates [WWW Document]. EnergySage. URL https://www.energysage.com/local-data/electricity-cost/mi/ (accessed 10.6.24).

Google Scholar ↗

[54] F.T. Pfeffer, N. Waitkus

The wealth inequality of Nations

Am. Sociol. Rev., 86 (2021), pp. 567-602, 10.1177/00031224211027800 ↗

View in Scopus ↗ Google Scholar ↗

[55] Free Beam Calculator | ClearCalcs [WWW Document], 2020 URL https://clearcalcs.com/freetools/beam-analysis (accessed 3.31.24).

Google Scholar ↗

Cited by (2)

Potential paths to Canada's climate commitments through strategic solar photovoltaic deployment

2025, E Prime Advances in Electrical Engineering Electronics and Energy

Show abstract

A Life-Cycle Carbon Reduction Optimization Framework for Production Activity Systems: A Case Study on a University Campus ↗

2025, Systems

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Public Comments (PCH) for: B109.4(1)-24

Discussion by Cindy Davis

Mar 11, 2026 23:29 UTC

Testing to see if this is where comments appear....

Discussion by Anthony Smith

Oct 29, 2025 23:14 UTC

These provisions apply to the review, permitting, and inspection of nonstructural electrical equipment and systems by third-party registered design professionals —including solar photovoltaic and HVAC installations—installed on existing residential and commercial buildings. The intent is to reduce administrative burdens on local governments, expedite approvals, and lower costs for property owners while maintaining full compliance with the USBC.

I would welcome comments and suggestions.

Tony Smith

tony@securesolarfutures.com

cell: 540-255-1404

Proposal # 1498

B109.4(1)-24 – Staff Summary

Proponent: Anthony Smith, Secure Solar Futures, representing Virginia Distributed Solar Alliance (VA-DSA)

Brief Description: Exempts construction documents for non-structural rooftop electrical equipment from plan review requirements when the permit application and plans are submitted by a licensed contractor or a Registered Design Professional. Requires permit issuance within two weeks of submission of the plans.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting – 01/06/2026

Support: Trieste Lockwood, Permit Power.

Opposition: Michael Dellinger, Albemarle County and Virginia Building and Code Officials Association (VBCOA) Region IV; Ron Clements, Chesterfield County and VBCOA Admin and Existing Building Code Committees; Rick Hinson, American Council of Engineering Companies (ACEC); Dan Willham, Fairfax County and VBCOA; Andrew Milliken, Stafford County Fire Marshal's Office, Virginia Fire Services Board Codes and Standards Committee (VFSB); Kyle Kratzer, Fairfax County and VBCOA**;** and Shahriar Amiri, Arlington County.

Discussion:

Maggie Davison (Secure Solar Futures, speaking on behalf of the proponent) provided an overview of the proposal.

a. **Ron Clements** expressed that this proposal prohibits plan review of solar installations. These could be huge installations with significant electrical and fire safety impacts on buildings. Effectively, the contractor will be able to self-certify their own code compliance. This really sets a dangerous precedent and what justifies this over other types of equipment?
b. **Dan Willham** added that this proposal would allow any system to be put on an existing roof without any kind of structural evaluation to see if the existing roof can hold the new load.
c. **Maggie D** countered that they are submitting a stamped structural letter, racking plan, and electrical plans. What they are finding is there are different interpretations of what existing building code needs to be applied. These are not permanent fixtures. **Maggie D** further explained that what they are seeking is consistency across localities and questioned if the

people reviewing these projects have the qualifications to understand what they are looking at.

d. **Shahriar Amiri** highlighted that the proposal does not require a structural drawing sealed and signed by an RDP. The RDP required in the exception could be an electrical engineer that has nothing to do with a structural evaluation. The other things to worry about are fire fighter access to the roof and for access for maintenance of the equipment.
e. **Michael Dellinger** contributed that class A contractors in his area that install solar equipment have no clue what firefighter access is. Giving them carte blanche is a bad idea.
f. **Andrew Milliken** suggested concern over using the term “rooftop electrical equipment”. If the proponent is talking about photovoltaic (PV) equipment, then call it that.

DHCD Staff Note:

This proposal is similar to portions of proposal B109.2-24, which was also reviewed by stakeholders at the third GSW meeting on January 6, 2026, and received a Non-Consensus recommendation.

B113.6-24

VCC: 113.6

Proponents: Andrew Clark, representing Home Builders Association of Virginia (aclark@hbav.com)

2021 Virginia Construction Code

Revise as follows:

113.6 Approval or notice of defective work. The building official shall either approve the work in writing or give written notice of defective work to the *permit holder*. ~~Upon request of the *permit holder*, the~~ The written notice shall reference the USBC section that serves as the basis for the defects and such defects shall be corrected and reinspected before any work proceeds that would conceal such defects. A record of all reports of inspections, tests, examinations, discrepancies and approvals issued shall be maintained by the building official and shall be communicated promptly in writing to the *permit holder*. Approval issued under this section may be revoked whenever it is discovered that such approval was issued in error or on the basis of incorrect information, or where there are repeated violations of the USBC. Notices issued pursuant to this section shall be permitted to be communicated electronically, provided the notice is reasonably calculated to get to the *permit holder*.

Reason Statement: Section 113.6 requires the building official to approve completed work in writing or issue a written notice of defective work. If requested by the permit holder, the written notice of defective work must cite the specific USBC section serving as the basis for the deficiency. This proposal removes the phrase “upon request of the permit holder”, requiring all notices of defective work to cite specific section(s) of the USBC serving as the basis for the deficiency.

The intent of this proposal is to provide builders with the information needed to efficiently make necessary corrections and minimize uncertainty or miscommunication that can lead to multiple inspections or project delays.

Cost Impact: The code change proposal will decrease the cost This proposal is expected to result in a modest reduction in cost. By requiring defect notices to include the applicable USBC section automatically, builders can identify and correct issues more efficiently, reducing time spent on clarification and follow-up inspections. The change also lessens administrative workload for both builders and building officials by minimizing back-and-forth communication and repeat site visits. Overall, it streamlines the inspection process without imposing any new compliance or reporting costs on localities.

B113.6-24 – Staff Summary

Proponent: Andrew Clark, Home Builders Association of Virginia (HBAV)

Brief Description: Requires all written notices of defective work to reference the USBC section that serves as the basis for the defects. Currently, the USBC section is only required to be referenced upon request of the permit holder.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting – 01/06/2026

Support: Shahriar Amiri, Arlington County; Kyle Kratzer, Fairfax County; Steve Shapiro, Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA); Andrew Milliken, representing himself; Dave Sharp, Fairfax County; Rick Hinson, American Council of Engineering Companies (ACEC); Chris Barfield, University of Virginia, Building Official's Office; and Ron Clements, Chesterfield County and Virginia Building and Code Officials Association (VBCOA) Admin and Existing Building Code Committees.

Opposition: Michael Dellinger, Albemarle County and VBCOA Region IV; Ricky Davis, Rockingham County; David Beahm, Warren County; Gregg Fields, City of Alexandria; and Mark Graver, City of Waynesboro and VBCOA Region III.

Discussion:

Andrew Clark provided an overview of the proposal.

a. **Shahriar Amiri** commented that this is how the code should be administered.
b. **Kyle Kratzer** [Fairfax County, Vice President of Virginia Building and Code Officials Association (VBCOA)] explained that he advocates to the students in his Virginia Building Code Academy classes to include code sections on their inspection results and plan reviews.
c. **Andrew Milliken** (speaking for himself), notes that this has been a fire code requirement for a long time.
d. **Dave Sharp** noted that this is a much-needed change and echoed **Kyle K** in that this is what is taught in Core.
e. **Michael Dellinger** objected to the Cost Impact statement that the proposal will decrease the cost because it will cost his jurisdiction a lot of money to include code sections with the code language because the current software they use cannot do that.
f. **Andrew M** commented that the proposal is just calling for a reference to a code section not the code section language verbatim.

g. **Andrew C** agreed with **Andrew M** that that was the intent.
h. **Michael D** stated that he does not like the idea of adding the code section number because that opens it up to an appeal if the wrong code section is cited. **Michael D** also highlighted that citing code sections is going to slow down inspections and increase cost.
i. **Andrew C** countered that it should save time and money by not having to go back and forth communicating with the builder.
j. **Shahriar A** called out that it is the code enforcers' duty and responsibility to cite the code they are enforcing.
k. **Ricky Davis** emphasized that small localities have combination inspectors and must deal with many different types of inspections on a job. It would slow them down to have to stop and look everything up. Many builders and homeowners do not even have code books, so they won't understand the code sections anyway.
l. **Andrew C** believed that giving a builder some more information will give them something to focus on which will result in less back and forth and may result in less re-inspections.
m. **Mark Graver** echoed **Ricky D's** comments and added that a lot of contractors do not want to know the code sections, they just want to be told what to do.
n. **Matthew Robinson** (speaking for himself), reminded the group that any document that code enforcers put forth is a legal document and they are not fully executing their job if they are not stating the code.

DHCD Staff Note: N/A

B113.7-24

VCC: 113.7, 113.7.1, 113.7.2

Proponents: Andrew Clark, representing Home Builders Association of Virginia (aclark@hbav.com)

2021 Virginia Construction Code

Revise as follows:

113.7 Approved inspection agencies. The building official ~~may~~ is authorized to accept reports of inspections and tests from individuals or inspection agencies approved in accordance with the building official's written policy required by Section 113.7.1 . ~~The individual or inspection agency shall meet the qualifications and reliability requirements established by the written policy.~~ The building official shall accept reports of inspections and tests for review when ~~Under circumstances where~~ the building official is unable to ~~make~~ complete the inspection or test required by Section 113.3 or 113.4 within 2 *working days* of a request or ~~an~~ a mutually agreed upon date or if authorized for other circumstances in the building official's written policy~~, the building official shall accept reports for review~~. The building official shall accept reports and tests for review of rooftop-mounted photovoltaic (PV) systems installed on one- and two-family dwellings or accessory structures when the building official is unable to complete the inspection or test required by section 113.3 or 113.4 with photographs or videotapes. The building official shall approve the report from such approved individuals or agencies unless there is cause to reject it. Failure to approve a report shall be in writing within 2 *working days* of receiving it stating the reason for the rejection. Reports of inspections conducted by approved third-party inspectors or agencies shall be in writing, shall indicate if compliance with the applicable provisions of the USBC have been met and shall be certified by the individual inspector or by the responsible officer when the report is from an agency. Photographs, videotapes, and other sources of pertinent data or information shall be considered as constituting such reports and tests and be incorporated into the third-party inspection policy pursuant to 113.7.1. Reports of inspections conducted for the purpose of verifying compliance with the requirements of the USBC for elevators, escalators, and related conveyances shall include the name and certification number of the elevator mechanic performing the tests witnessed by the third-party inspector or agency.

Exception: The licensed mechanical contractor installing the mechanical system shall be permitted to perform duct tests required by Section R403.3.5 of the IECC or Section N1103.3.5 of the IRC. The contractor shall have been trained on the *equipment* used to perform the test.

~~Note:~~ ~~Photographs, videotapes or other sources of pertinent data or information may be considered as constituting such reports and tests.~~

113.7.1 Third-party inspectors. Each building official charged with the enforcement of the USBC shall have a written policy establishing the minimum acceptable qualifications for third-party inspectors. The policy shall include the format and time frame required for submission of reports, any prequalification or preapproval requirements before conducting a third-party inspection and any other requirements and procedures established by the building official. The written policy shall also provide for acceptance of inspection and test reports for rooftop-mounted photovoltaic (PV) systems installed on one- and two-family dwellings or accessory structures. Applications for prequalification, preapproval, or other procedures required prior to conducting a third-party inspection shall be reviewed and acted upon by the building official within three (3) working days of receipt of a complete application.

113.7.2 Qualifications. In ~~determining~~ establishing third-party inspector qualifications, the building official ~~may~~ shall consider such items as *DHCD* inspector certification, licensure as a Registered Design Professional (RDP) in the Commonwealth of Virginia, other state or national certifications, state professional registrations, related experience, education and any other factors that would demonstrate competency and reliability to conduct inspections.

Reason Statement: Many local building departments across Virginia are experiencing staffing shortages that affect their ability to complete required inspections within statutory timeframes. These delays extend project schedules, increase carrying costs, and slow the construction of new housing and the installation of rooftop-mounted photovoltaic (PV) systems. This proposal seeks to expand the use of qualified third-party inspectors to supplement local inspection capacity, ensure timely project completion, and maintain consistent enforcement of the Uniform Statewide Building Code.The proposal revises Section 113.7 of the 2021 Virginia Residential Code (VRC) to

clarify and expand the use of qualified third-party inspectors, including:

- Editorial changes to existing provisions related to the local building officials authority of accept report from approved third-party inspectors and timeframe in which the local building official must accept a third-party inspectors report for review.
- Clarifies that local policies must allow for the acceptance of inspection and test reports for rooftop-mounted photovoltaic (PV) systems installed on one- and two-family dwellings or accessory structures.
- Requires local building officials to act on prequalification or preapproval applications within three working days of receipt.
- Provides that photographs, videos, and similar documentation may serve as valid inspection evidence.
- Expands qualification criteria by recognizing Registered Design Professionals (RDPs) licensed in Virginia as eligible third-party inspectors, along with DHCD-certified and other credentialed individuals.

Proponents: Permit Power (Trieste Lockwood) and Home Builders Association of Virginia (Andrew Clark)

Cost Impact: The code change proposal will decrease the cost This proposal will reduce construction costs by an indeterminate amount through improved inspection efficiency and reduced project delays.

B113.7-24 – Staff Summary

Proponent: Andrew Clark, Home Builders Association of Virginia (HBAV)

Brief Description: Adds third-party inspection requirements specific to rooftop-mounted photovoltaic (PV) systems installed on one- and two-family dwellings and accessory structures.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting – 01/06/2026

Support: None

Opposition: Shahriar Amiri, Arlington County; Ron Clements, Chesterfield County and Virginia Building and Code Officials Association (VBCOA) Admin and Existing Building Code Committees; Andrew Milliken, Stafford County Fire Marshal's Office and Virginia Fire Services Board (VFSB); David Beahm, Warren County and VBCOA; Mark Graver, City of Waynesboro and VBCOA Region III; and Michael Dellinger, Albemarle County and VBCOA Region IV.

Discussion:

Andrew Clark provided an overview of the proposal.

a. **Trieste Lockwood** (Permit Power) conveyed that the intent is to streamline third party inspection processes for rooftop-mounted photovoltaic (PV) systems.
b. **Shahriar Amiri** questioned why there is a carve out for PV systems. Shahriar A also brought up that building officials cannot issue a code violation based on a photograph that someone else provides.
c. **Andrew Milliken**, speaking for himself, asked the proponent to clarify the intent, explaining that as written, the proposal appears to mandate the acceptance of third-party inspection reports (which could include videos or photos) if the jurisdiction does not allow photographs or videos as part of the inspection by the locality. He noted that the concept floated around before is, if the jurisdiction cannot meet the timeline for the inspection, then they must allow third party inspections, but the proposal does not say that.
d. **Trieste L** explained that the intent was that if the building department offers remote inspection, then you would need to have a third-party policy. She agreed that it could benefit from rewording.
e. **Andrew M** shared concern that photographs and videos are not tests and inspections.
f. **David Beahm** expressed opposition to the language requiring three working days for third-party applications.

g. **Mark Graver** clarified that a photograph and a videotape do not constitute a report.
h. **Michael Dellinger** voiced concern over the proposal taking away the building official's ability to approve third party inspection agencies and what the minimum requirements they must meet. **Michael D** also had concerns over licensure as a Registered Design Professional (RDP), being a qualifying criterion for a third-party inspector as there are plenty of RDPs who know nothing about building code.

DHCD Staff Note: N/A

B434-24

VCC: SECTION 202 (New), 108.1, 312.1, 434 (New)

Proponents: Michael McCabe, representing Myself (mikeamccabe@gmail.com)

2021 Virginia Construction Code

Add new text as follows:

Bomb Shelter. Bomb shelter: a structure designed to protect its occupants from explosives, fire, and weapons of mass destruction for a minimum of 30 days.
Bomb shelters must protect occupants from explosive blast effects up to 50 psi, biological agents, chemical weapons, radioactive particles, fire and smoke. Bomb shelters must have an occupancy equal to the building(s) above it, and which have access to it; they must also be capable of withstanding said building(s) collapsing upon them without any loss to the occupants' protection.
Protection Factor. A protection factor (PF) refers to the amount of exposure to a harmful substance (radioactive, chemical, biological, etc.) an individual receives, relative to how much he would receive if standing in the open.
For instance, if a bomb shelter has a PF of 40 against radioactive particles, then an individual inside the shelter would receive a dose of radiation 40 times smaller than the dose he would receive if standing in the open. This can be achieved both through the use of certain materials and through optimal designs.

Revise as follows:

108.1 When applications are required. Application for a permit shall be made to the building official and a permit shall be obtained prior to the commencement of any of the following activities, except that applications for emergency *construction*, alterations or *equipment* replacement shall be submitted by the end of the first *working day* that follows the day such work commences. In addition, the building official may authorize work to commence pending the receipt of an application or the issuance of a permit.

1. *Construction* or demolition of a *building or structure*. Installations or alterations involving (i) the removal or addition of any *wall*, partition or portion thereof, (ii) any structural component, (iii) the repair or replacement of any required component of a fire or smoke rated assembly, (iv) the alteration of any required means of egress system, including the addition or removal of *emergency supplemental hardware*, (v) water supply and distribution system, sanitary drainage system or vent system, (vi) electric wiring, (vii) fire protection system, mechanical systems, or fuel supply systems, (viii) bomb shelters, or

(ix) any *equipment* regulated by the USBC.

2. For *change of occupancy*, application for a permit shall be made when a new certificate of occupancy is required by the VEBC .
3. Movement of a lot line that increases the hazard to or decreases the level of safety of an *existing building* or *structure* in comparison to the *building* code under which such *building* or *structure* was constructed.
4. Removal or disturbing of any asbestos containing materials during the *construction* or demolition of a *building* or *structure*, including additions.

312.1 General. Buildings and structures of an accessory character and miscellaneous structures not classified in any specific occupancy shall be constructed, equipped and maintained to conform to the requirements of this code commensurate with the fire and life hazard incidental to their occupancy. Group U shall include, but not be limited to, the following:

Agricultural buildings

Aircraft hangars, accessory to a one- or two-family residence (see Section 412.4)

Barns

Bomb Shelters

Carports

Communication equipment structures with a *gross floor area* of less than 1,500 square feet (139 m^2)

Fences more than 7 feet (2134 mm) in height

Grain silos, accessory to a residential occupancy

Livestock shelters

Marinas

Private garages

Retaining walls

Sheds

Stables

Tanks

Towers

Add new text as follows:

434 Bomb Shelters. Bomb shelters differ from storm shelters in that they must protect the occupants from more serious hazards for a longer period of time. Bomb shelters must be constructed with a protection factor (PF) of 1000 or more. They must be well-ventilated, protect against carbon monoxide and radon poisoning, while filtering out biological, chemical, and radiological agents. They must also provide adequate water for drinking and sanitation; 30 gallons per occupant is an acceptable minimum. Adequate storage for survival supplies and repair kits for all essential systems is important. All ventilation, cooling, and sanitation systems must be operable by hand in the event of power failure, and luminescent strips can be used to guide occupants. Faraday cages shall also be included to protect occupants' electronics against electromagnetic pulses.
Bomb shelters will be kept narrow; should their occupancy need to be increased, it shall be accomplished by increasing length so as to maintain roof integrity.

Reason Statement: Bomb shelters are desirable tools for saving lives in a bombing attack, whether from conventional bombs or CBRN (Chemical, Biological, Radiological, Nuclear) weapons. Attempting to build a few large, public shelters is impractical; conversely, Switzerland has successfully built bomb shelters in every new construction since the 1960s. Thus, bomb shelter standards should be oriented towards smaller, more numerous shelters that can be quickly accessed in an emergency. These should, to the greatest extend possible, also be useful in peacetime.

Cost Impact: The code change proposal will increase the cost Locales which mandate bomb shelters will see a noticeable increase in construction costs.

Attached Files

- **Emergency Exit.pdf**
  https://va.cdpaccess.com/proposal/1280/1804/files/download/915/
- **Fire and Carbon Monoxide Protections.pdf**
  https://va.cdpaccess.com/proposal/1280/1804/files/download/914/
- **Shelter Ventilation Pump.pdf**

https://va.cdpaccess.com/proposal/1280/1804/files/download/913/

- **Ventilation of Shelters.pdf**
  https://va.cdpaccess.com/proposal/1280/1804/files/download/912/
- **Permanent Family Fallout Shelters.pdf**
  https://va.cdpaccess.com/proposal/1280/1804/files/download/911/
- **Double-action filter.pdf**
  https://va.cdpaccess.com/proposal/1280/1804/files/download/910/
- **Blast Shelters.pdf**
  https://va.cdpaccess.com/proposal/1280/1804/files/download/909/

Appendix F

Means for Providing Improved Natural Ventilation and Daylight to a Shelter with an Emergency Exit

THE NEED

Survivors in areas of heavy fallout can greatly reduce the radiation doses that they will receive, and thus decrease their risks of contracting cancer, if they sleep and spend many of their non-outdoor-working hours inside good shelters during the first several months after an attack. (See *Minimizing Excess Radiogenic Cancer Deaths After a Nuclear Attack,* by Kathy S. Gant and Conrad V. Chester, Health Physics, September 1981.)

A permanent family shelter can serve quite well for months as a post-attack temporary home if it is designed to provide adequate natural ventilation most of the time, to have adequate and easy forced ventilation by a KAP when forced ventilation is needed, and to have daylight illumination. A shelter dependent on ventilation laboriously pumped through pipes and on artificial lights even during daytime is much less practical for use as a post-attack home.

The following instructions should enable a family having an earth-covered shelter with an emergency exit to make it much more livable for months-long occupancy. The means described below for providing improved ventilation and daylight illumination also will supply guidance to survivors who will build shelters post-attack to minimize continuing radiation exposures, especially to children and pregnant women.

BUILDING AND USING A MULTI-PURPOSE EMERGENCY EXIT HOUSING

Build a multi-use emergency exit housing of the design pictured in Fig. F.1 and detailed in Fig. F.2. Size your exit housing to fit snugly over the top of your **completed** vertical exit shaft. This exit housing is made of 3/4-inch exterior plywood, four 2 x 2 x 36-inch boards, and four 16 x 16-inch window panes of 1/8-inch Plexiglas. Plated screws and waterproof adhesives are used to assure sturdiness and durability.

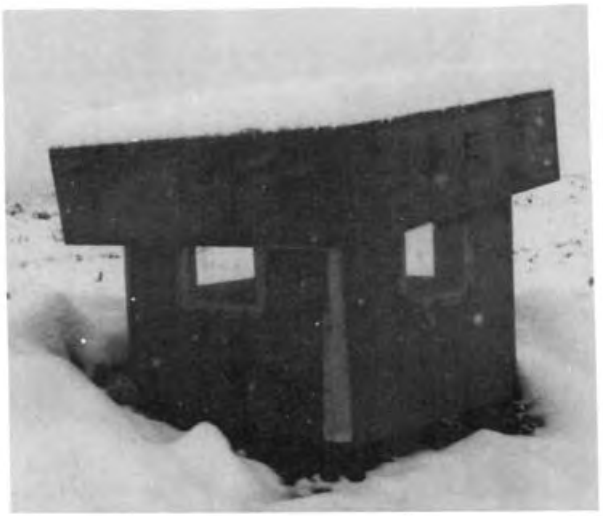


Fig. F.1. Multi-Use Emergency Exit Housing Installed Over the Square Emergency Exit Described by Figs. 17.1, 17.2, and 17.3.

The adjustable top of this exit housing measures 4 x 4 x 1 feet, and can be tilted to make different sized ventilation openings in any of four directions. The top also can be raised straight up to make various sized openings all the way around, or it can be completely closed — as explained by Fig. F.2 and the following descriptions of its uses.

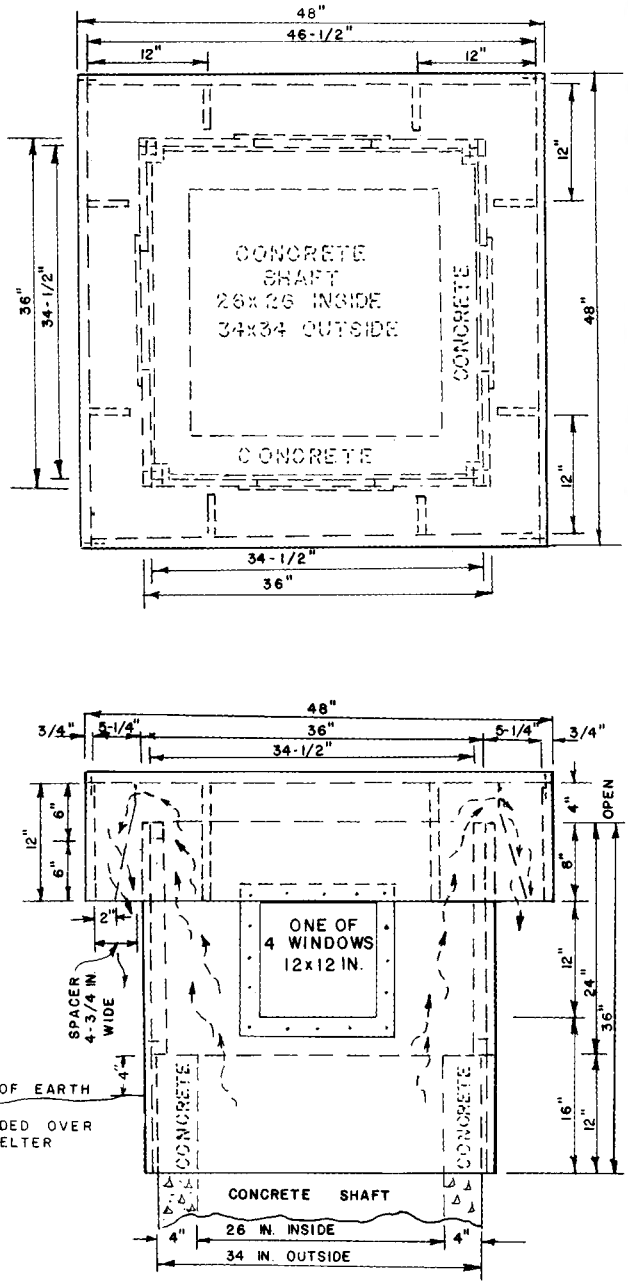


Fig. F.2. Plan and Side View of Multi-Purpose Emergency Exit Housing, on a Square Emergency Exit with 34 x 34-Inch Cross-Sectional Outside Dimensions.

In Figs. F.2 and F.3, note the eight bevelled plywood guides, two on the inside of each side of the top. These guides are needed so that the top can be tilted in the position desired, merely by using a stick to raise it from below. To hold the top in a tilted or raised position, spacer boards are placed between the raised top and the upper edges of a wall or walls, as illustrated by Fig. F.4.



Fig. F.3. The Top and Four Walls of the Multi-Purpose Emergency Exit Housing, Nested Together to Save Storage Space.



Fig. F.4. View from Below the Exit, Looking Up the Multi-Purpose Emergency Exit Housing. The top is shown supported in a tilted position by two 6-inch-wide boards placed between a wall and the top.

The illustrated housing over a vertical exit provides:

* A means to regulate shelter ventilation, and to increase natural ventilation when the wind is blowing. If, for example, the shelter's opened exit is to the north of its opened entry and a north wind is blowing, shelter airflow will blow in through the exit and out through the entry. This natural ventilating airflow, often inadequate, is increased if the adjustable top of the exit housing is not simply raised 6 inches on all four sides, but is tilted as shown in Fig. F.1, with its south side closed and its north side tilted up 6 inches to provide a 6 x 26-inch ventilation opening between the upper edge of the entry housing's north wall and its top. Then a north wind striking the north wall produces

increased air pressure over and above this wall, forcing more air into the exit and on through the shelter. In contrast, if a south wind is blowing, natural airflow will go in through the shelter's entry and out through its exit. And if the adjustable top still is tilted open to the north as illustrated, then reduced air pressure over and above the downwind north wall will "suck" an increased airflow out of the exit and through the shelter.

The measured increases in airflows through a small shelter resulting from the top of this exit housing being tilted were only 40-50 cfm when an 8-10 mph breeze was blowing. These rather small increases in airflow, however, often would make it unnecessary to supply forced ventilation to a family shelter by intermittently operating a KAP.

* Exclusion of rain, snow, and larger dust and fallout particles. The four 12 x 48-inch vertical sides of the adjustable top overhang the exit housing's walls by 6 to 12 inches. Thus the top serves as a large ventilation hood over the exit, preventing rain, snow, and larger dust and fallout particles from entering while ventilation is continuing. (To prevent entry of flies and mosquitoes, an insect screen panel, made to fit over the bottom of the emergency exit, should be kept stored in the shelter until needed. A screen door for the inner entry doorway also should be stored. Remember that installing screens greatly reduces natural ventilation airflows.)

* A reliable source of daylight. The four 12 x 12-inch windows of this exit housing let enough daylight into the exit shaft, that is painted white, to permit a person on the shelter floor below to read, even for several minutes after sunset. See Fig. F.4.

* A way to observe what is going on all around the shelter, without having to go outside, and with lessened exposure to fallout radiation.

* Quick installation post-attack, after fallout decays sufficiently. In an installation test, dirt was dug away to expose the upper 12 inches of the emergency exit shaft. Then in just 8 minutes the author and a boy carried the 5 parts of this exit housing 80 feet, positioned its four walls around the already exposed upper 12 inches of the reinforced concrete emergency exit, nailed its walls together, and placed its adjustable top in the tilted position pictured in Fig. F.1.

BUILDING AND USING AN ENTRYWAY COVER THAT PROVIDES A LARGE, PROTECTED VENTILATION OPENING

Build a shelter entryway cover that keeps out rain, snow, and the bigger dust and fallout particles while providing a large, protected ventilation opening both for natural ventilation and for easy forced ventilation by a KAP when needed. For an example of one type of entryway cover, see Fig. F.5. This photo shows a 4-piece cover, that two men in a little less than 5 minutes carried out of this shelter and installed over the 4 x 6-foot opening above the shelter's opened stairway doors.

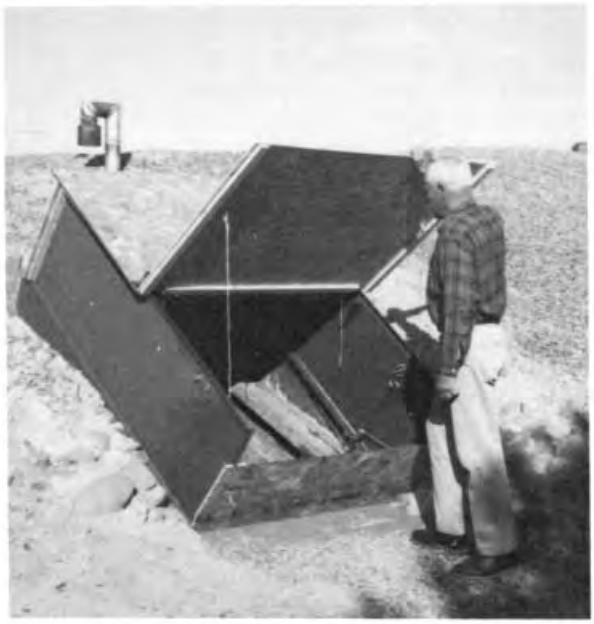


Fig. F.5. A Quickly Installable, 4-Piece Entryway Cover That Provides Easy Access and a Large, Protected Ventilation Opening.

This cover is made of 4 pieces of 1/4-inch chipboard, each 5 feet wide, and short lengths of nailed-on 1 x 2-inch boards. These 4 pieces can be tied quickly with their attached nylon cords to inner parts of the two 2 x 6-foot steel entryway doors, which are pictured in their opened, upright positions.

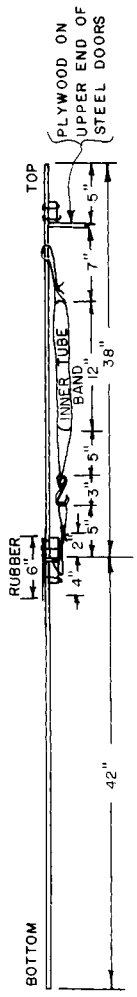
The lowermost of the 4 chipboard pieces has a groove near each end. The grooves are each made of 2 nailed-on lengths of 1 x 2 lumber spaced apart to fit the lower ends of the doors and hold them in their upright positions 4 feet apart. The upper edge of this lowermost piece is 8 inches below the lower raised corners of the doors, so that an 8 x 48-inch ventilation opening is assured when the lower of the two large covering pieces (pictured being held open) rests on the doors. (This step-over piece of chipboard illustrates a way to reduce the quantity of larger fallout particles that will be blown into many types of shelters, because most sandlike particles and coarse dust are blown along close to the ground. They are not blown upward and over a vertical obstruction by most winds. If an entryway has an inner, ordinary doorway, even more fallout particles can be kept out of the shelter room if an 18 x 18-inch ventilation hole is cut in

the door near its top. Then air entering the shelter room will have to rise at least 4 feet above the entryway floor, and most of the larger fallout particles will be deposited on the entryway floor.)

The chipboard piece attached to the upper ends of the doors also has two 1 x 2 boards nailed near each end, forming grooves into which the upper ends of the doors fit. The doors are thus held in their upright positions and rain, etc. is kept from falling or being blown through the upper end into the entryway.

The uppermost of the two large covering pieces of chipboard (or exterior plywood) rests on the opened doors and is kept from slipping down by a 1 x 2-inch board nailed 4 inches from its upper end. This small board "hooks" over the upper edge of the piece of chipboard (or plywood) attached to the upper ends of the steel doors. (See the drawing on the side of this column.) This large piece of chipboard is securely tied to the doors.

To keep the two large pieces from moving sideways, one 1 x 2-inch board is nailed near each of their side edges, spaced so as to lie against the outside of each opened, upright steel door. To strengthen the hingeline edge of the upper large covering piece, a 1 x 2-inch board is nailed along its lower edge.



The lower of the two large covering pieces also has a reinforcing 1 x 2 nailed near its hinged edge.

The most practical hinge that the author has devised is illustrated by the drawing. This flexible hinge is much less likely to be broken than are conventional hinges, and makes it easier to build the two large covering pieces to fit over the opened doors. Note that the upper edge of the lower large piece goes under the rainproofing, 6-inch-wide rubber flap, which is nailed only along the lower edge of the upper large covering piece. Then the two large pieces are held and hinged together by first stretching each of 2 strong, 2-inch-wide rubber bands (or rustproof springs) attached by cords to the upper large covering piece, and then hooking its attached bent-wire hook onto a nylon cord loop connected to the lower large covering piece. Each strong rubber band (cut from a truck innertube) and its attached hook and nylon cords is 5 inches from an opened door. Thus hinged, the lower large piece can be easily raised to permit a person to step out of or into the stairway entry. When this hinged lower large piece is closed and tied down, a 2.7 square foot protected ventilation opening with a 10-inch overhang results.

OTHER ENTRYWAY COVERS TO PROVIDE LARGE PROTECTED OPENINGS FOR NATURAL AND KAP VENTILATION

The owner of a permanent shelter with an emergency exit may be able to improvise coverings over its entry and exit after fallout decays sufficiently to permit work outdoors — provided that he understands natural ventilation and low-pressure forced ventilation requirements, and has the boards, nails, pieces of chipboard or plywood or canvas, tools, etc. needed. But if you own a permanent shelter your pre-crisis preparations surely should include making and storing ready-to-install entryway and exit coverings of whatever designs you decide will best meet your anticipated needs for high-protection-factor sleeping and living quarters during weeks or months following a nuclear attack.

Chapter 7

Protection Against Fires and Carbon Monoxide

RELATIVE DANGERS

Fire and its consequences probably would be the third-ranking danger to unprepared Americans subjected to a massive nuclear attack. Direct blast effects would be first, covering a large fraction of densely populated areas and killing far more people. Considerably fewer fatalities seem likely to result from the second-ranking danger, fallout radiation.

THE FACTS ABOUT FIRE HAZARDS

Firestorms would endanger relatively few Americans; only the older parts of a few American cities have buildings close enough together, over a large enough area, to fuel this type of conflagration. Such fires have not occurred in cities where less than about 30% of a large area was covered with buildings.[19]

In the blast area of Hiroshima, a terrifying fire storm that burned almost all buildings within an area of about 4.4 square miles resulted from many fires being ignited almost simultaneously. Many were caused by heat radiation from the fireball. Even more fires were due to secondary effects of the blast, such as the overturning of stoves. The buildings contained much wood and other combustible materials. The whole area burned like a tremendous bonfire; strong winds that blew in from all directions replaced the huge volumes of hot air that rose skyward from the intense fires.

Lack of oxygen is not a hazard to occupants of shelters in or near burning buildings or to those in shelters that are closed tightly to prevent the entry of smoke or fallout. Carbon monoxide, toxic smoke from fires, or high concentrations of carbon dioxide from shelter occupants' exhaled breaths would kill occupants before they suffered seriously from lack of oxygen.

FIRES IGNITED BY HEAT RADIATION

Figure 7.1 shows a wood-frame house after it was heated for one second by heat radiation from a small nuclear weapon exploded in a Nevada test. This test house had no furnishings, but the heat was intense enough to have ignited exposed upholstery, curtains, bedding, papers, etc. in a typical home.

Heat radiation will set fire to easily ignitable materials (dry newspapers, thin dark fabrics, dry leaves and dry grass) in about the same extensive areas over which blast causes moderate damage to frame houses. The blast wave and high-speed blast winds will blow out many flames. However, tests have shown that fire will continue to smolder within some materials such as upholstery and dry rotted wood, and after a while it often will burst into flame and will spread. The burning automobile pictured in Fig. 7.2 is an example of such ignition beyond the range of severe blast damage.

The number of fires started by heat radiation in areas where blast is not severe can be reduced by whitewashing the insides of window panes and by removing flammable materials from places in and around houses where heat radiation could reach them. Also, occupants of shelters in some homes that would be only slightly damaged by blast could move quickly to extinguish small fires and throw out smoldering upholstered articles before fallout is deposited.



Fig. 7.1. Heat radiation charred the paint on this house, which had been painted white to reflect heat rays. The charring instantaneously produced the smoke. However, precautions had been taken to prevent this typical U.S. house from being destroyed by fire, because the test was made to enable engineers to study the effects of blast, rather than fire. The house was demolished by the 5-psi overpressure blast that struck seconds later, but it did not burn.



Fig. 7.2. Thermal radiation from a nuclear explosion entered the car above through its closed windows and ignited the upholstery. The windows were blown out by the blast a few seconds later. However, the explosion was at such a distance that the blast wave was not severe enough to dent the car body.

Earth-covered shelters can be protected against heat radiation from nuclear explosions and other causes by painting any exposed wood and other combustible materials at shelter openings with a thick coating of slaked lime (old-fashioned whitewash). The World War II firebombing of Kassel was less effective than were similar raids on other German cities because the roof timbers of buildings had been so treated.[20]

Figure 7.3 illustrates the effectiveness of a thick coating of slaked lime in protecting a rough pine board against ignition by heat radiation. No flames from the burning logs touched the board. (Before this photograph was taken, the uppermost burning logs of a vertical-sided pile were removed so that the board could be seen clearly.)

Chinese civil defense instructions recommend coating exposed wood with both slaked lime and mud.[21] If only mud is available, a coating of it protects wood quite well. If kept damp, a mud coating is even more effective. (Simply keeping all exposed flammable materials damp is helpful.)

In blast areas, cloth or plastic canopies over the openings of expedient shelters usually would be ignited by the heat and certainly would be blown away by even moderate blast winds. If extra canopies and stakes could be made and kept inside the shelter, these replacements could be quickly erected after blast winds subside and before fallout begins—at least 15 minutes after the explosion. If no spare canopies were available, it would be best to keep the available canopies and their stakes inside the shelter, if it were not raining.

FOREST AND BRUSH FIRES

Unless forests or brushy areas are dry, it is difficult to start even scattered fires. Dangerous mass fires would be unlikely, except in blast areas where the heat radiation would be very intense. However, people building a shelter would do well to select a shelter site at least as far away from trees as the height of the tallest tree that could fall on the shelter—because of fire and smoke hazards in dry weather, and because digging a shelter among tree roots is difficult.



Fig. 7.3. Heat radiation had ignited the flaming half of the board on the ground, while the half near the shovel—painted white with a thick coating of slaked lime—had not even begun to smoke.

CAUSES OF FIRE

Figure 7.4 pictures the same house shown in Fig. 7.1 after it had been struck by the blast effects of a small nuclear test explosion at the 5-psi overpressure range. (If the house had been hit by the blast effects of a multimegaton weapon, with longer-lasting blast winds, it would have been wrecked about as completely at the 3-psi overpressure range. At the 3-psi overpressure range, the blast winds from an explosion 1000 times as powerful as the Nevada test explosion that wrecked this house would blow 10 times as long. This longer-duration, 100-mph blast wind would increase the damage done by the blast wave. The 3-psi overpressure range from a 20-megaton surface burst is about 10 miles from the center of the crater, and from a one-megaton surface burst, about 4 miles.[6])

If the blast-wrecked house shown in the illustration had had a furnace in operation when it was demolished, the chances of its being set on fire would have been high. In Hiroshima many of the first fires resulted from secondary effects of blast, especially the overturning of stoves, and not from heat radiation. Although the air burst produced no fallout, firefighters from undamaged, nearby communities were unable to reach most of the burning areas because of blast debris blocking the roads. Later they were kept from burning areas by the intense heat. Some water mains were broken, which made water unavailable for firefighting in certain areas.

In the event of an attack on the United States employing many surface bursts, fallout would prevent firefighting for days to weeks in a large part of the most populated regions.

The basements of many substantial buildings will withstand 5-psi blast effects and can prevent occupants from suffering serious injuries from blast. Most home basements can be reinforced with stout boards and posts so as to give good protection against blast effects up to considerably higher than 5 psi. But considering the dangers of fires in probable blast areas, it is safer to build an earth-covered shelter well removed from buildings than it is to seek protection in shelters inside buildings.

CARBON MONOXIDE AND TOXIC SMOKE

If an undamaged building is burning, people inside may be killed by carbon monoxide, toxic smoke, or fiery-hot air. Tests have shown that even fast-burning, rubble-free fires produce very high concentrations of carbon monoxide. If large-scale fires are burning near a shelter, the dangers from both carbon dioxide and carbon monoxide may continue for as long as $1\frac{1}{2}$ hours after ignition.[22] Therefore, the ventilation pipes or openings of a shelter should not be placed close to a building that might be expected to burn.

In the smoldering rubble of a large test fire, after 24 hours the carbon monoxide concentration was still more than 1% and the air temperature was



Fig. 7.4. Unburned wreckage of the same two-story, wood-frame house pictured in Fig. 7.1 after being wrecked by the 5-psi blast effects of a small nuclear test explosion.

1900°F. A carbon monoxide concentration of only 0.08% (8 parts CO in 10,000 parts of air) will cause headache, dizziness, and nausea in 45 minutes, and total collapse in 2 hours.

Realization of carbon monoxide dangers to persons in simple fallout shelters and basements may have led the writers of Soviet civil defense publications to define the "zone of total destruction" as the blast areas where the overpressure exceeds 7 psi and "residential and industrial buildings are completely destroyed ... the rubble is scattered and covers the burning structures," and "As a result the rubble only smolders, and fires as such do not occur."[23] Smoldering fires produce more carbon monoxide than do fiercely burning fires. Whether or not the occupants of basement shelters survive the direct blast effects is of little practical importance in those blast areas where the rubble overhead burns or smolders. So in the "zone of complete destruction," Russian rescue brigades plan to concentrate on saving persons trapped inside excellent blast shelters by the rubble.

About 135,000 Germans lost their lives in the tragic city of Dresden during three days of firebomb raids. Most casualties were caused by the inhalation of hot gases and by carbon monoxide and smoke poisoning.[20] Germans learned that when these dangers were threatening an air raid shelter, the occupants' best chance of survival was to run outside, even if the bombs were still falling. But in a nuclear war the fallout dose rate may be so high that the occupants of a shelter threatened by smoke and carbon monoxide might suffer a more certain and worse death by going outside. Instead, if they know from instrument readings and their calculations that they probably would receive a fatal dose before they could reach another shelter, the occupants should close all openings as tightly as possible. With luck, carbon monoxide in deadly concentrations would not reach them, nor would they be overcome by heat or their own respiratory carbon dioxide before the fire dangers ended.

Dr. A.Broido, a leading experimenter with fires and their associated dangers, reached this conclusion: "If I were building a fallout shelter I would spend a few extra dollars to build it in my backyard rather than in my basement, locating the intake vent as far as possible from any combustible material. In such a shelter I would expect to survive anything except the close-in blast effects."[22]

This advice also applies to expedient shelters built during a crisis.

Appendix B
How to Make and Use a Homemade Shelter-Ventilating Pump, the KAP

I. THE NEED FOR SHELTER AIR PUMPS

In warm weather, large volumes of outside air MUST be pumped through most fallout or blast shelters if they are crowded and occupied for a day or more. Otherwise, the shelter occupants' body heat and water vapor will raise the temperature-humidity conditions to DANGEROUSLY high levels. If adequate volumes of outdoor air are pumped through typical belowground shelters in hot weather, many times the number of persons could survive the heat than otherwise could survive in these same shelters without adequate forced ventilation. Even in cold weather, about 3 cubic feet per minute (3 cfm) of outdoor air usually should be pumped through shelters, primarily to keep the carbon dioxide exhaled by shelter occupants from rising to harmful concentrations.

The KAP (Kearny Air Pump) is a practical, do-it-yourself device for pumping adequate volumes of cooling air through shelters—with minimum work. The following instructions have been improved repeatedly after being used by dozens of small groups to build KAPs—including families, pairs of housewives, and children. None of these inexpert builders had previously heard of this kind of pump, yet almost all groups succeeded in making one in less than 4 hours after assembling the materials. Their successes prove that almost anyone, if given these detailed and thoroughly tested instructions, can build a serviceable, large-volume air pump of this simple type, using only materials and tools found in most American homes.

If possible, build a KAP large enough to pump through your shelter at least 40 cubic feet per minute (40 cfm) of outdoor air for each shelter occupant. If 40 cfm of outdoor air is pumped through a shelter and distributed within it as specified below, even under heat-wave conditions the effective temperature of the shelter air will not be more than 2° F higher than the effective temperature outdoors. (The effective temperature is a measure of air's effects on people due to its heat, humidity, and velocity.) The 36-inch-high by 29-inch-wide KAP described in these instructions, if used as specified, will pump at least 1000 cfm of outside air through a shelter that has the airflow characteristics outlined in these instructions.

If more than 25 persons might be expected to occupy a shelter during hot weather, then it is advisable to build a larger KAP. The 72-inch-high by 29-inch-wide model described can pump between 4000 and 5000 cfm.

To maintain tolerable temperature-humidity conditions for people in your shelter during hot weather, you **must:**

- Pump enough outdoor air all the way through the shelter (40 cfm for each occupant in very hot, humid weather).

- Distribute the air evenly within the shelter. If the KAP that pumps air through the shelter does not create air movement that can be felt in all parts of the shelter in hot weather, one or more additional KAPs will be needed to circulate the air and gently fan the occupants.

- Encourage the shelter occupants to wear as little clothing as practical when they are hot. (Sweat evaporates and cools best on bare skin.)

- Supply the occupants with adequate water and salt. For prolonged shelter occupancy under heat-wave conditions in a hot part of the country, about 4 quarts of drinking water and $^1/_3$ ounce (1 tablespoon) of salt per person are required every 24 hours, including salt in food that is eaten. Normal American meals supply about $^1/_4$ ounce of salt daily. Salt taken in addition to that in food should be dissolved in the drinking water.

- Pump outdoor air through your shelter day and night in warm weather, so that both the occupants and the shelter are cooled off at night.

Almost all of the danger from fallout is caused by radiation from visible fallout particles of heavy, sand-like or flakey material. The air does **not** become radioactive due to the radiation continuously given off by fallout particles.

The visible fallout particles rapidly "fall out" of slow moving air. The air that a KAP pumps through a shelter moves at a low speed and could carry into the shelter only a very small fraction of the fallout particles that cause the radiation hazard outside. This fraction, usually not dangerous, can be further reduced if occupants take the simple precautions described in these instructions.

CAUTION

Before anyone starts to build this unusual type of air pump, ALL WORKERS SHOULD READ THESE INSTRUCTIONS AT LEAST UP TO **SECTION V, INSTALLATION.** Otherwise, mistakes may be made and work may be divided inefficiently.

When getting ready to build this pump, all workers should spend the first half-hour studying these instructions and getting organized. Then, after materials are assembled, two inexperienced persons working together should be able to complete the 3-foot model described in the following pages in less than 4 hours. To speed up completion, divide the work; for example, one person can start making the flaps while another begins work on the pump frame.

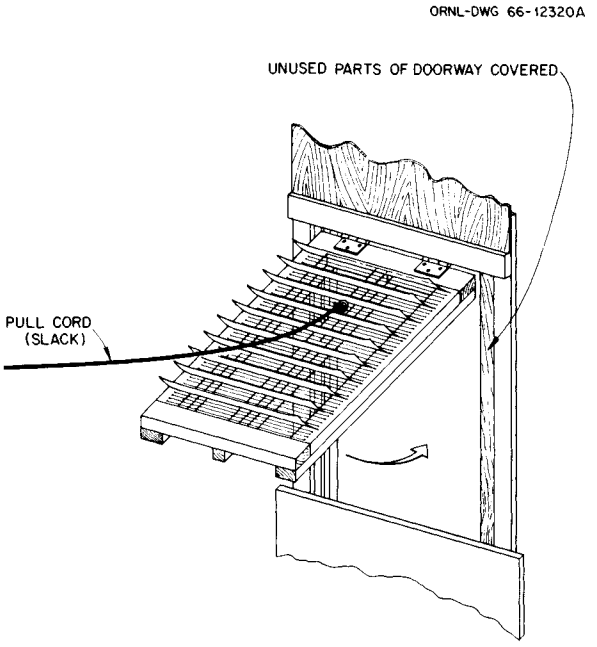


Fig. 1. Section through the upper part of a doorway, showing operation of a KAP.

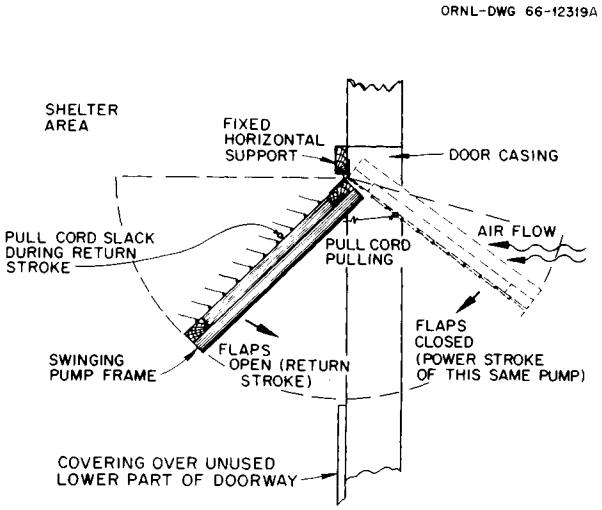


Fig. 2. KAP in doorway (with flaps open during its return stroke).

II. HOW A KAP WORKS

As can be seen in Figs. 1 and 2, a KAP operates by being swung like a pendulum. It is hinged at the top of its swinging frame. When this air pump is pulled by a cord as illustrated, its flaps are closed by air pressure and it pushes air in front of it and "sucks" air in back of it. Thus a KAP pumps air through the opening in which it swings. This is the power stroke. During its power stroke, the pump's flaps are closed against its flap-stop wires or strings, which are fastened across the face of the frame.

When a KAP swings freely back as a pendulum on its return stroke, all its flaps are opened by air

pressure. The pumped air stream continues to flow in the direction in which it has been accelerated by the power stroke, while the pump itself swings in the opposite direction (see Fig. 2). Thus the flaps are one-way valves that operate to force air to flow in one direction, where desired.

The KAP can be used: (1) to supply **outdoor** air to a shelter, (2) to distribute air within a shelter, and/or to fan the occupants.

1. To force **outdoor** air **through** a shelter, an **air-supply** KAP usually is operated as an air-intake pump by pulling it with a cord (see Fig. 1). (Only rarely is it necessary to operate a KAP as an air-exhaust pump by pushing it with a pole, as described in the last section of these instructions.)

2. To distribute air **within** a shelter and/or to fan the occupants, **air-distribution** KAPs may be hung overhead and operated as described later.

III. INSTRUCTIONS FOR BUILDING A KAP

In this section, instructions are given for making a KAP 36 inches high and 29 inches wide, to operate efficiently when swinging in a typical home basement doorway 30 inches wide. If your doorway or other ventilation opening is narrower or wider than 30 inches, you should make your KAP 1 inch narrower than the narrowest opening in which you plan to install it. Regardless of the size of the KAP you plan to build, first study the instructions for making the 36 × 29-inch model.

In Section VII you will find brief instructions for making a narrower and even simpler KAP, one more suitable for the narrow openings of small trench shelters and other small expedient shelters. Section VIII covers large KAPs, for large shelters.

A. Materials Needed for a KAP 36 inches High by 29 inches Wide

The preferred material is listed as first (1st) choice, and the less-preferred materials are listed as (2nd), (3rd), and (4th) choices. It is best to assemble, spread out, and check all your materials before beginning to build.

1. The pump frame and its fixed support:

- Boards for the frame:

  (1st) 22 ft of 1 × 2-in. boards. (A nominal 1 × 2-in. board actually measures about $^{3}/_{4} \times 1\text{-}^{3}/_{4}$ in., but the usual, nominal dimensions will be given throughout these instructions.) Also, 6 ft of 1 × 1-in. boards. Soft wood is better.

  (2nd) Boards of the same length that have approximately the same dimensions as 1 × 2-in. and 1 × 1-in. lumber.

  (3rd) Straight sticks or metal strips that can be cut and fitted to make a flat-faced KAP frame.

- Hinges: (1st) Door or cabinet butt-hinges; (2nd) metal strap-hinges; (3rd) improvised hinges made of leather, woven straps, cords, or 4 eyescrews which can be joined to make 2 hinges. (Screws are best for attaching hinges. If nails are used, they should go through the board and their ends should be bent over and clinched—flattened against the surface of the board.)

- A board for the fixed horizontal support: (1st) A 1 × 4-in. board that is at least 1 ft longer than the width of the opening in which you plan to swing your pump; (2nd) A wider board.

- Small nails (at least 24): (1st) No. 6 box nails, about $^{1}/_{2}$ in. longer than the thickness of the two boards, so their pointed ends can be bent over and clinched); (2nd) other small nails.

2. The flaps (See Figs. 1, 2, 6, 7, and 8):

- Plastic film or other **very light,** flexible material—12 square feet in pieces that can be cut into 9 rectangular strips, each 30 × $5^{1}/_{2}$ in.: (1st) polyethylene film 3 or 4 mils thick (3 or 4 one-thousandths of an inch); (2nd) 2-mil polyethylene from large trash bags; (3rd) tough paper.

- Pressure-sensitive waterproof tape, enough to make 30 ft of tape $^{3}/_{4}$ in. to 1 in. wide, for securing the hem-tunnels of the flaps: (1st) cloth duct tape (silver tape); (2nd) glass tape; (3rd) scotch tape; (4th) freezer or masking tape, or sew the hem tunnels. (Do not use a tape that stretches: it may shrink afterward and cause the flaps to wrinkle.)

3. The flap pivot-wires:

(1st) 30 ft of smooth wire at least as heavy and springy as coat hanger wire, that can be made into **very straight** pieces each 29 in. long (nine all-wire coat hangers will supply enough); (2nd) 35 ft of somewhat thinner wire, including light, flexible insulated wire; (3rd) 35 ft of smooth string, preferably nylon string about the diameter of coat hanger wire.

4. The pull cord:

(1st) At least 10 ft of cord; (2nd) strong string; (3rd) flexible, light wire.

5. The flap-stops:

- (1st) 150 ft of light string; (2nd) 150 ft of light, smooth wire; (3rd) 150 ft of very strong thread; (4th) 600 ft of ordinary thread, to provide 4 threads for each stop-flap.
- (1st) 90 tacks (not thumbtacks); (2nd) 90 small nails. (Tacks or nails are desirable but not essential, since the flap-stops can be tied to the frame.)

B. Tools

A hammer, saw, wirecutter pliers, screwdriver, scissors, knife, yardstick, and pencil are desirable. However, only a strong, sharp knife is essential for making some models.

C. Building a KAP 36 inches High by 29 inches Wide

A 36 × 29-in. KAP is most effective if operated in an air-intake or exhaust opening about 40 in. high and 30 in. wide. (If your shelter might have more than 25 occupants in hot weather, read all these instructions so you will understand how to build a larger pump, briefly described in Section VIII.)

NOTE THAT THE WIDTHS AND THICKNESSES OF ALL FRAME PIECES ARE EXAGGERATED IN ALL ILLUSTRATIONS.

1. The frame

a. Cut two pieces of 1 × 2-in. boards, each 36 in. long, and two pieces of 1 × 2-in. boards, each 29 in. long; then nail them together(see Fig. 3). Use nails that do not split the wood, preferably long enough to go through the boards and stick out about $^1/_2$ in. on the other side. (To nail in this manner, first put blocks under the frame so that the nail points will not strike the floor.) Bend over nail points which go through.

Next, cut and nail to the frame a piece of 1 × 1-in. lumber 36 in. long, for a center vertical brace. (If you lack time to make or to find a 1 × 1-in. board, use a 1 × 2-in. board.) Figure 3 shows the back side of the frame; the flap valves will be attached on the front (the opposite) side.

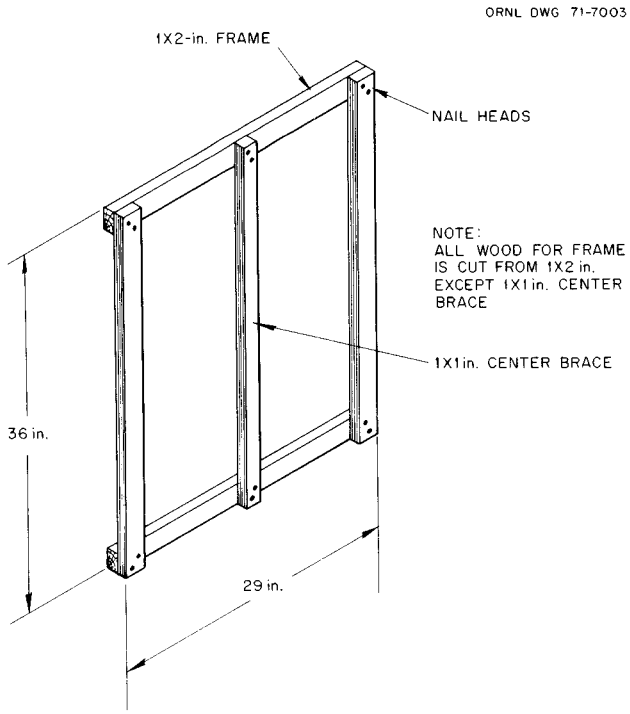


Fig. 3. KAP frame (looking at the back side of the frame).

b. To make the front side smooth and flat so that the flaps will close tightly, fill in the spaces as follows: Cut two pieces of 1 × 2-in. boards long enough to fill in the spaces on top of the 36-in. sides of the frame between the top and bottom horizontal boards, and nail these filler boards in place. Do the same thing with a 1 × 1-in. board (or a board the size of that used for the center brace) as a filler board for the center brace (see Fig. 4).

If the frame is made of only one thickness of board $^3/_4$ in. to 1 in. thick, it will not be sufficiently heavy to swing back far enough on its free-swinging return stroke.

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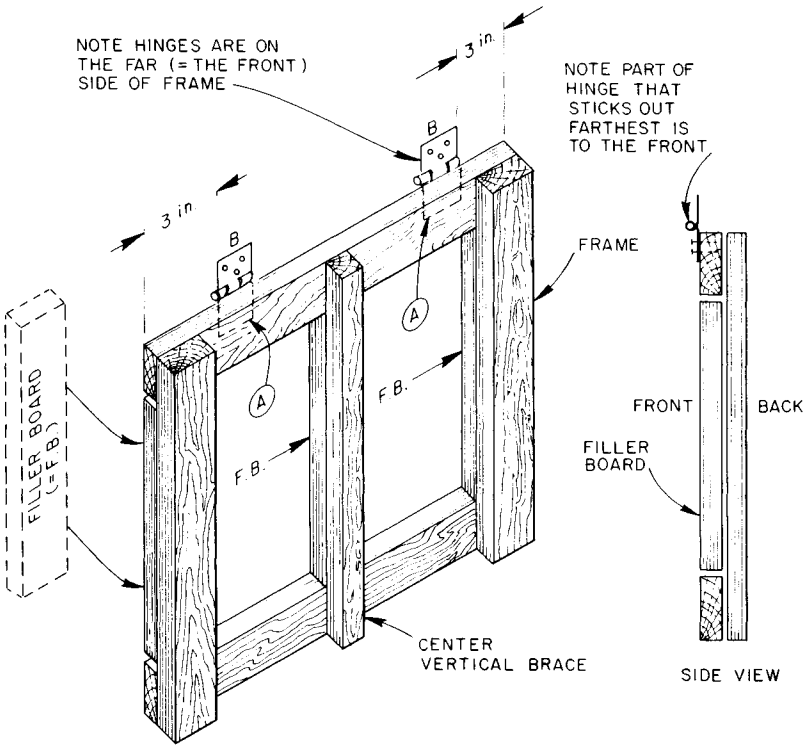


Fig. 4. Completing the frame.

2. The hinges

Ordinary door butt-hinges are best. So that the pump can swing past the horizontal position, the hinges should be screwed onto the front of the frame, at its top, in the positions shown in Fig. 4. (Pick one of the 29-in. boards and call it the top.) If you do not have a drill for drilling a screw hole, you can make a hole by driving a nail and then pulling it out. Screw the screw into the nail hole.

3. The pivot-wires and flaps

a. Make 9 flap pivot-wires. If you have smooth, straight wire as springy and thick as coat hanger wire, use it to make **nine** 29-in.-long straight lengths of wire. If not, use wire from all-wire coat hangers or use strings. First, cut off all of the hook portion of each coat hanger, including the twisted part. If you have only ordinary pliers, use the cutter to "bite" the wire all around; it will break at this point if bent there. Next, **straighten** each wire **carefully.** Straighten all the bends so that each wire is straight within $^1/_4$ in., as compared to a straight line. Proper straightening takes 1 to 5 minutes per wire. To straighten, repeatedly grasp the bent part of the wire with pliers in slightly different spots, each time bending the wire a little with your other hand. Then cut each wire to a 29-in. length. Finally, bend no more than $^1/_2$ in. of each end at a right angle and in the same plane—that is, in directions so that all parts of the bent wire will lie flat against a smooth surface. The bent ends are for secure attachment later (see Fig. 8).

b. Make 9 polyethylene flaps that will be the hinged valves of the KAP. First cut 9 strips, making each strip 30 in. long by $5^1/_2$-in. wide (see Fig. 5). To cut plastic flaps quickly and accurately, cut a long strip of plastic 30 in. wide. Then cut off a flap in this way: (1) draw a cutting guideline on a wide board $5^1/_2$ in. from an edge; (2) place the 30-in.-wide plastic strip so that it lies on this board, with one of the strip's side edges just reaching the edge of the board; (3) place a second board over

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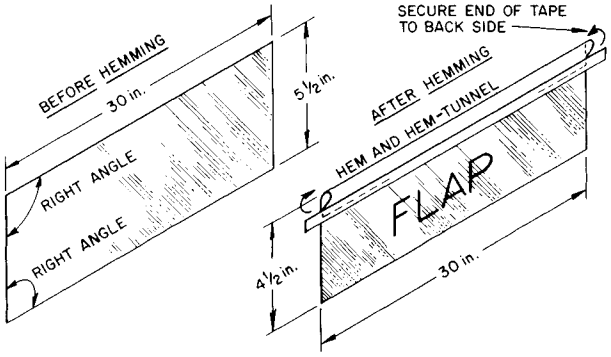


Fig. 5.

the plastic on the first board, with a straight edge of this second upper board over the guideline on the lower board; and finally (4) cut off a flap by running a **sharp** knife along the straight edge of the upper board.

To form a hem along one of the 30-in. sides of a $5^1/_2 \times 30$-in. rectangular strip, fold in a **1-in.** hem. This makes the finished flap $4^1/_2$ in. wide.

To hold the folded hem while taping it, paper clips or another pair of hands are helpful. For each hem, use two pieces of pressure-sensitive tape, each about 1 in. wide and 16 in. long. Or make the hem by sewing it very close to the cut edge to form a hem-tunnel (see Fig. 5).

After the hem has been made, cut a notch with scissors in each hemmed corner of the flap (Figs. 6 and 8). Avoid cutting the tape holding the hem. Each notch should extend downward about $^1/_2$ in. and should extend horizontally from the outer edge of the flap to $^1/_4$ in. inside the inner side of the frame, when the flap is positioned on the frames as shown in Fig. 6.

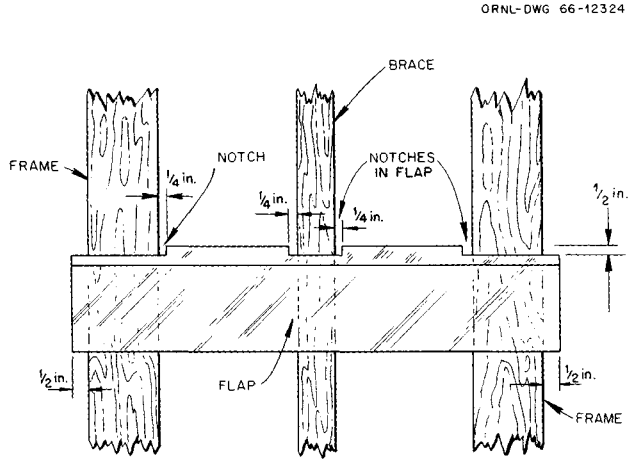


Fig. 6. Sizes of notches in flaps.

Also cut a notch in the center of the flap (along the hem line) extending $^1/_2$ in. downward and extending horizontally $^1/_4$ in. beyond each of the two sides of the vertical brace (see Fig. 6). The notch MUST be wider than the brace. [However, if you are building a pump using wire netting for flap-stops (see Fig. 13), then do NOT cut a notch in the center of each flap.]

c. Take the 9 pieces of straightened wire and insert one of them into and through the hem-tunnel of each flap, like a curtain rod running through the hem of a curtain. Check to see that each flap **swings freely** on its pivot-wire, as illustrated by Fig. 7. Also see Fig. 8.

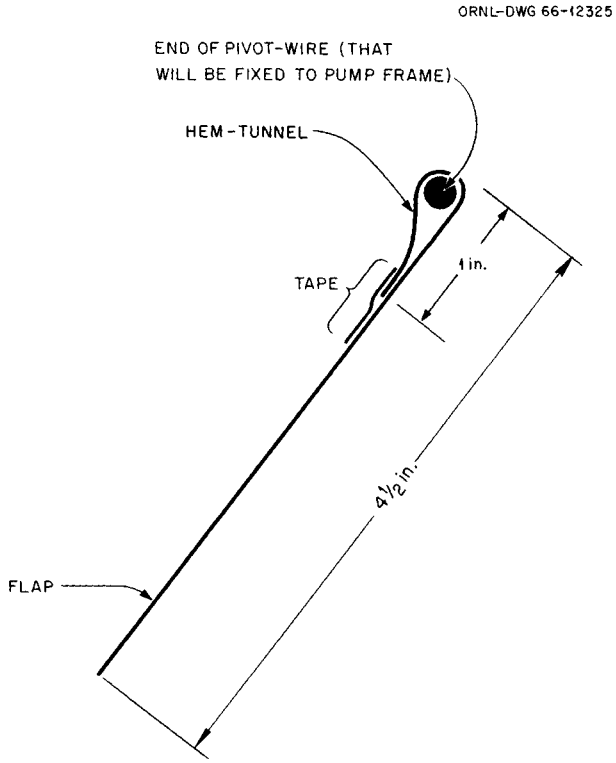


Fig. 7. End view.

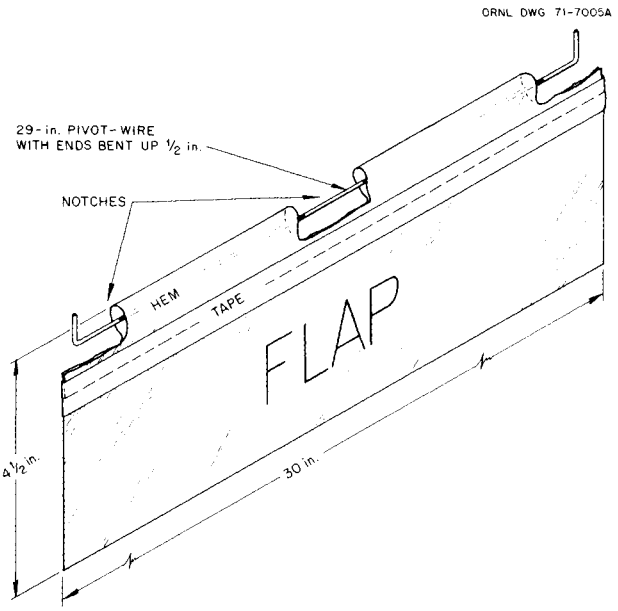


Fig. 8.

d. Put aside the flaps and their pivot-wires for use after you have attached the flap-stops and the hinges to the frame, as described below.

e. Using the ruler printed on the edge of this page, mark the positions of each pivot-wire (the arrowheads numbered 0, $3^5/_8$, $7^1/_4$ in.) and the position of each flap-stop (the four marks between each pair of numbered arrowheads on this ruler). All of these positions should be marked both on the vertical sides of the 36-in.-long boards of the frame and on the vertical brace. Mark the position of the uppermost pivot-wire (the "0" arrowhead on this ruler) $^1/_4$ in. below the top board to which the hinges have been attached (see Figs. 9 and 10).

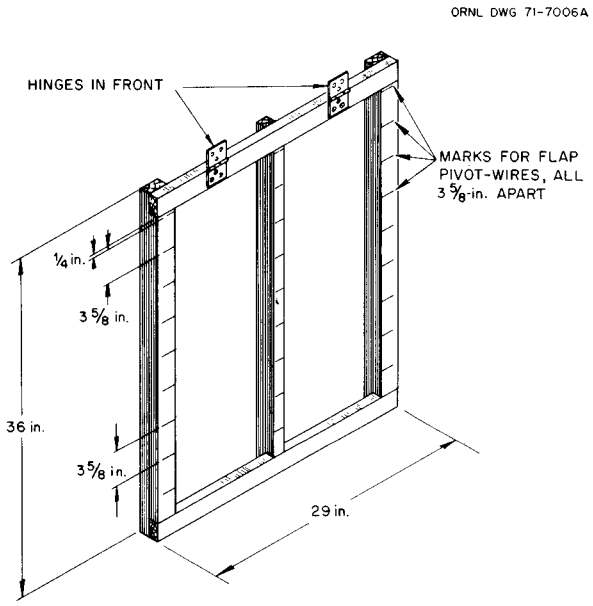


Fig. 9.

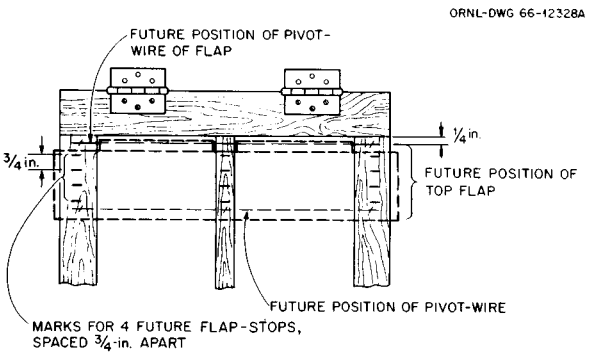


Fig. 10.

4. The flap-stops

So that the flaps may swing open on only one side of the frame (on its front, or face), you must attach horizontal flap-stops made of strings or wires across the face of the frame. (See Figs. 10 and 11.) Nail or tie four of these flap-stops between the marked points where each pair of the horizontal pivot-wires for the flaps will be placed. Be careful not to connect any flap-stops in such a way that they cross the horizontal open spaces in which you later will attach the flap pivot-wires.

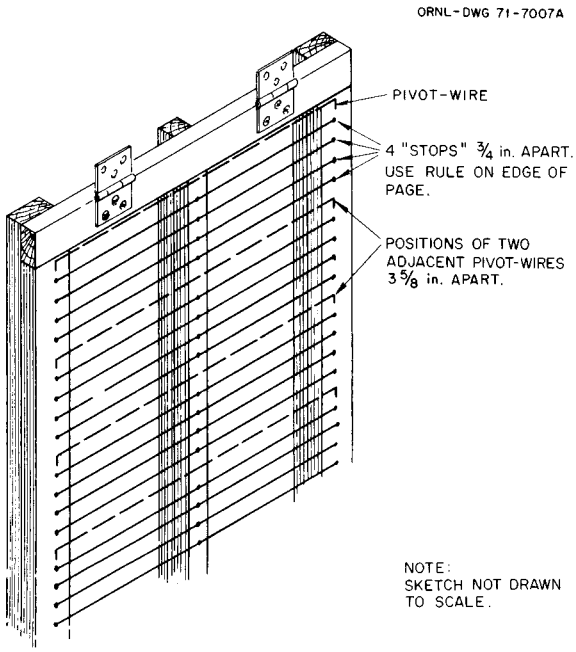
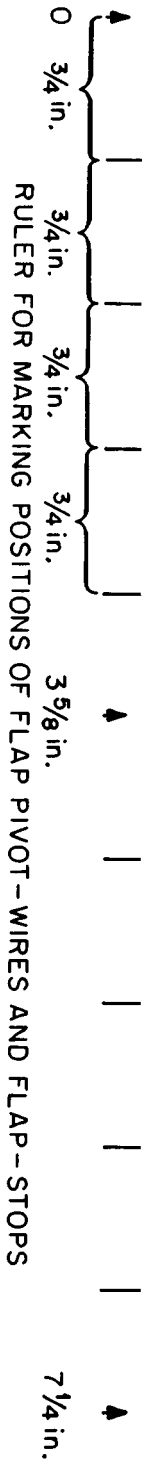


Fig. 11. Positions of pivot-wires and flap-stops.

If you have tacks (NOT thumbtacks) or very small nails, drive three in a horizontal line to attach each flap-stop—one in each of the two vertical 36-in. sides of the frame and one in the vertical center brace (see Fig. 11). First, drive all of these horizontal lines of tacks about three-quarters of the way into the boards. Then, to secure the flap-stop string or thin wire quickly to a tack, wind the string around the tack and immediately drive the tack tightly into the frame to grip the string (see Fig. 11).

If you have no tacks or nails, cut notches or slots where the flap-stops are to be attached. Cut these notches in the edges of the vertical sides of the frame and in an edge of the center brace. Next, secure the flap-stops (strings or wires) by tying each



one in its notched position. This tying should include wrapping each horizontal flap-stop once around the vertical center brace. The stops should be in line with (in the same plane as) the front of the frame. Do not stretch flap-stops too tightly, or you may bend the frame.

5. Final assembly

a. Staple, nail, or tie the 9 flap pivot-wires or pivot-strings (each with its flap attached) in their positions at the marked $3^5/_8$-in. spacings. Start with the lowest flap and work upward (see Fig. 11). Connect each pivot-wire at both ends to the 36-in. vertical sides of the frame. **Also connect it to the vertical brace.** BE CAREFUL TO NAIL THE PIVOT-WIRES ONLY TO THE FRAME AND THE BRACE. DO NOT NAIL ANY PLASTIC DIRECTLY TO THE WOOD. All flaps must turn freely on their pivot-wires.

If any flap, when closed, overlaps the flap below it by more than 1 in., trim off the excess so that it overlaps by only 1 in.

b. Screw (or nail, if screws are not available) the upper halves of the hinges onto the horizontal support board on which the KAP will swing. (A 1-in.-thick board is best, $3^1/_2$ in. wide and at least 12 in. longer than the width of the doorway or other opening in which this KAP is to be installed.)

Be careful to attach the hinges in the UNusual, OUT-OF-LINE POSITION shown in Fig. 12.

CAUTIONS: Do NOT attach a KAP's hinges directly to the door frame. If you do, the hinges will be torn loose on its return stroke or on its power stroke.

If you are making a KAP to fit into a rectangular opening, make its frame 4 in. SHORTER than the height of its opening and 1 in. NARROWER than the width of the opening.

c. For this 3-ft model, tie the pull-cord to the center brace about **$12^1/_2$ in. below the hinge line,** as shown in Fig. 12. (If you tie it lower, your **arm movements will waste energy.**) Use small nails or wire to keep the tie end from slipping up or down on the center brace. (For a more durable connection, see Fig. 22.)

Cut a slot in the flap above the connection of the pull-cord to the vertical brace, deep enough so that this flap will close completely when the KAP is being pulled. Tape the end and edges of the slot.

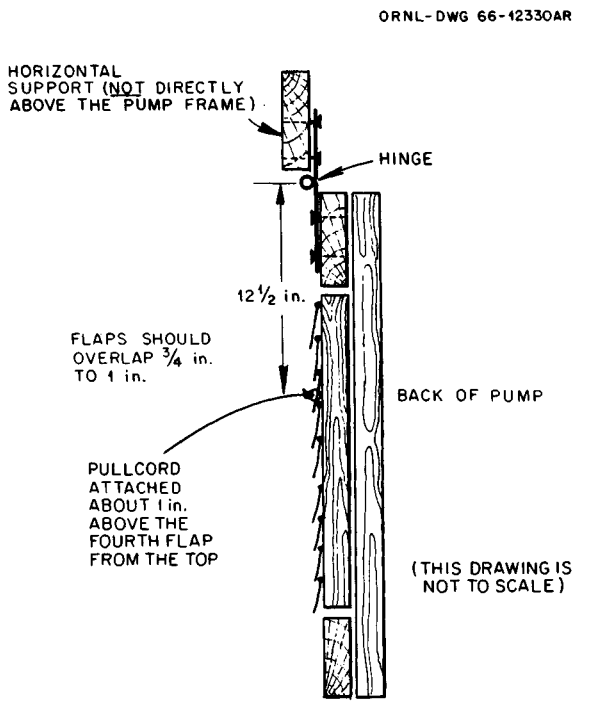


Fig. 12. Hinge is attached so pump can swing 180 degrees.

IV. MORE RAPID CONSTRUCTION

(Skip this section if you cannot easily get chicken wire and $^1/_4$-in.-thick boards.)

If chicken wire and boards about $^1/_4$ in. thick are available, use the chicken wire for flap-stops. By using these materials, the time required to build a given KAP can be reduced by about 40%. One-inch woven mesh is best. (Hardware cloth has sharp points and is unsatisfactory.)

Figure 13 illustrates how the mesh wire should be stapled to the KAP frame. Next, unless the KAP is wider than 3 ft, the front of the whole frame (except for the center brace) should be covered with thin boards approximately $^1/_2$ in. thick, such as laths. Then the pivot-wires, with their flaps on them, should be stapled onto the $^1/_4$-in.-thick boards. This construction permits the flaps to turn freely in front of the chicken-wire flap-stops.

With this design, the center of each pivot-wire should NOT be connected to the center brace, nor should the center of the flap be notched. However, pivot-wires that are attached this way must be made and held straighter than pivot-wires used with flap-stops made of straight strings or wires.

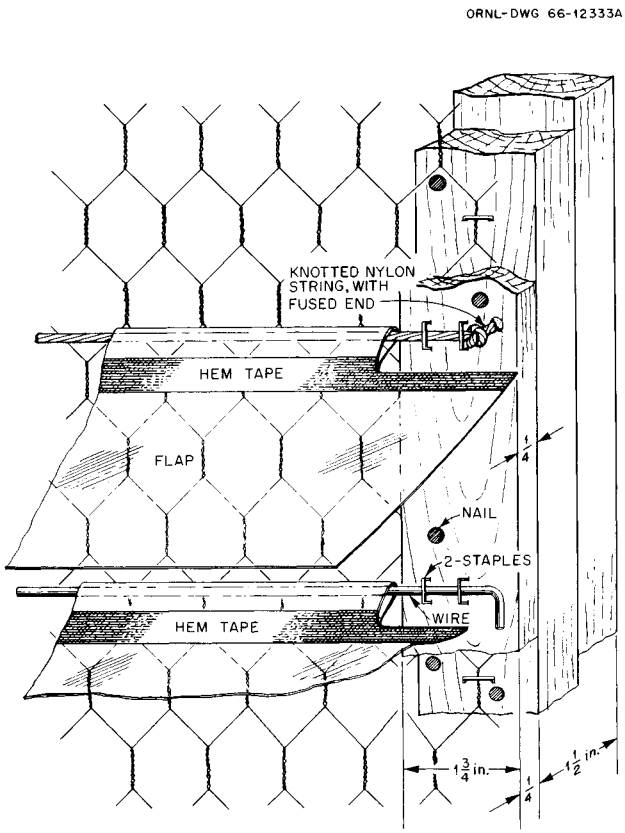


Fig. 13. Flaps attached $^1/_4$ inch in front of chicken wire used for flap-stops.

Note in Fig. 13 that each pivot-wire is held firm and straight by **2** staples securing each end. The wire used should be at least as springy as coat hanger wire. If string is used instead of wire, nylon cord about the diameter of coat hanger wire is best for the pivot-strings.

If the KAP is wider than 3 ft, its center vertical brace should also be covered with a $^1/_4$-in.-thick board, and each pivot-wire should be attached to it. Furthermore, the center of each flap should be notched.

V. INSTALLATION AND ACCESSORIES

A. Minimum Open Spaces Around a KAP

To pump its maximum volume, an air-supply KAP with good metal hinges should be installed in its opening so that it swings only about $^1/_2$ in. above the bottom of the opening and only $^1/_2$ in. to 1 in. from the sides of the opening.

B. Adequately Large Air Passageways

When using a KAP as an air-supply pump to force air through a shelter, it is essential to provide a **low-resistance** air passageway **all the way through** the shelter structure from an **outdoor** air-intake opening for **outdoor** air to a separate air-exhaust opening to the **outdoors** (see Fig. 14).

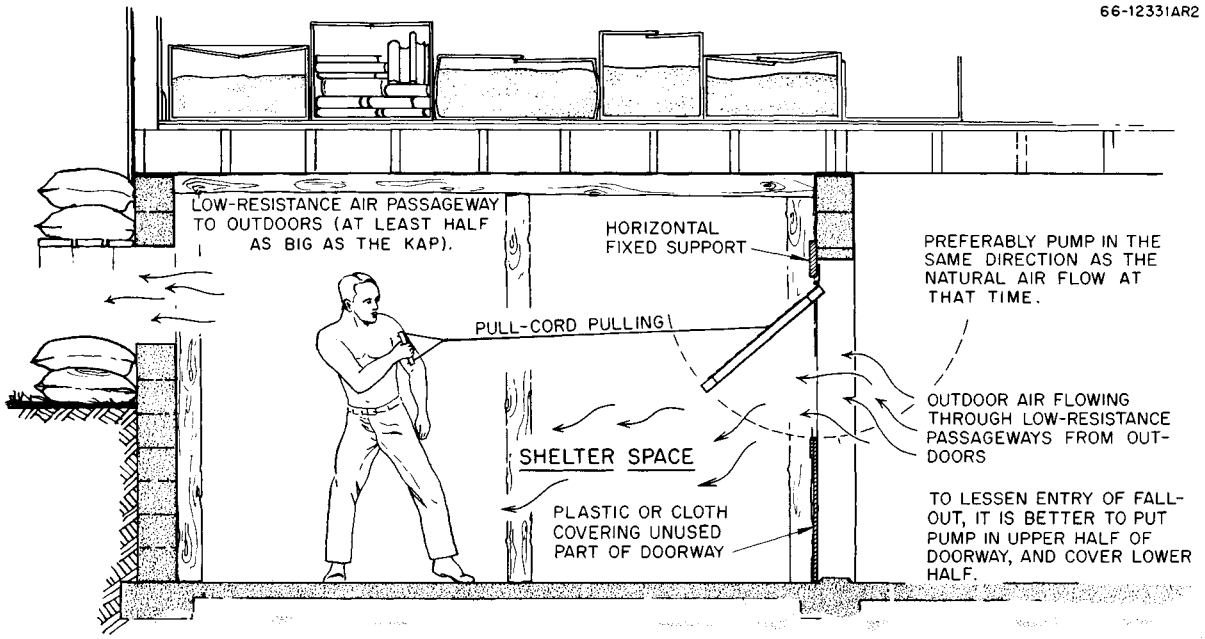


Fig. 14.

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A low-resistance air passageway is one that is **no smaller** in cross-sectional area than half the size of the KAP pumping the air. For example, a 36 × 29-in. KAP should have a passageway no smaller than about 3½ sq. ft. An air-supply KAP of this size will force at least 1000 cubic feet per minute (1000 cfm) through a shelter having such openings, if it is installed as illustrated in Fig. 14.

If smaller air passageways or air-exhaust openings are provided, the volume of air pumped will be greatly reduced. For example, if the air-exhaust opening is only 1¾ sq. ft (¼ the size of this KAP), then this KAP will pump only about 500 cfm. And if the air-exhaust opening is only a 6 × 6-in. exhaust duct (¼ sq. ft), then this same 36 × 29-in. KAP will pump only about 50 cubic feet per minute. This would not provide enough outdoor air for more than one shelter occupant in a well-insulated shelter under heat-wave conditions in the hottest humid parts of the United States. In contrast, when the weather is freezing cold and the shelter itself is still cold enough to absorb the heat produced by the shelter occupants, this same 6 × 6-in. exhaust duct and the air-intake doorway will cause about 50 cfm of outdoor air to flow by itself through the shelter without using any pump. The reason: body heat warms the shelter air, and the warm air rises if cold air can flow in to replace it. Under these **cold** conditions—provided the air is distributed evenly throughout the shelter by KAP or otherwise—50 cfm is enough outdoor air for about 17 people.

To provide adequately large air passageways for air-supply KAPs used to ventilate shelters in buildings, in addition to opening and closing doors and windows, it may be necessary to build large ducts (as described below). Breaking holes in windows, ceilings, or walls is another way to make large, efficient air passageways.

Figure 15 illustrates how a 3-ft KAP can be used as a combined air-supply and air-distribution pump to adequately ventilate a small underground shelter that has an exhaust opening too small to provide enough ventilation in warm weather. (A similar installation can be used to ventilate a basement room having only one opening, its doorway.) Note how, by installing a "divider" in the doorway and entryway, the single entryway is converted into a large air-intake duct and a separate, large air-exhaust duct. To obtain the maximum increased volume of fresh outdoor air that can be pumped through the shelter—a total of about 1000 cfm for a 36 × 29-in. KAP—the divider should extend about 4 ft horizontally into the shelter room, as shown in Fig. 15. The 6 ft at the end of the divider (the almost-horizontal part under the KAP) can be made of plywood, provided it is installed so that it can be taken out of the way in a few seconds.

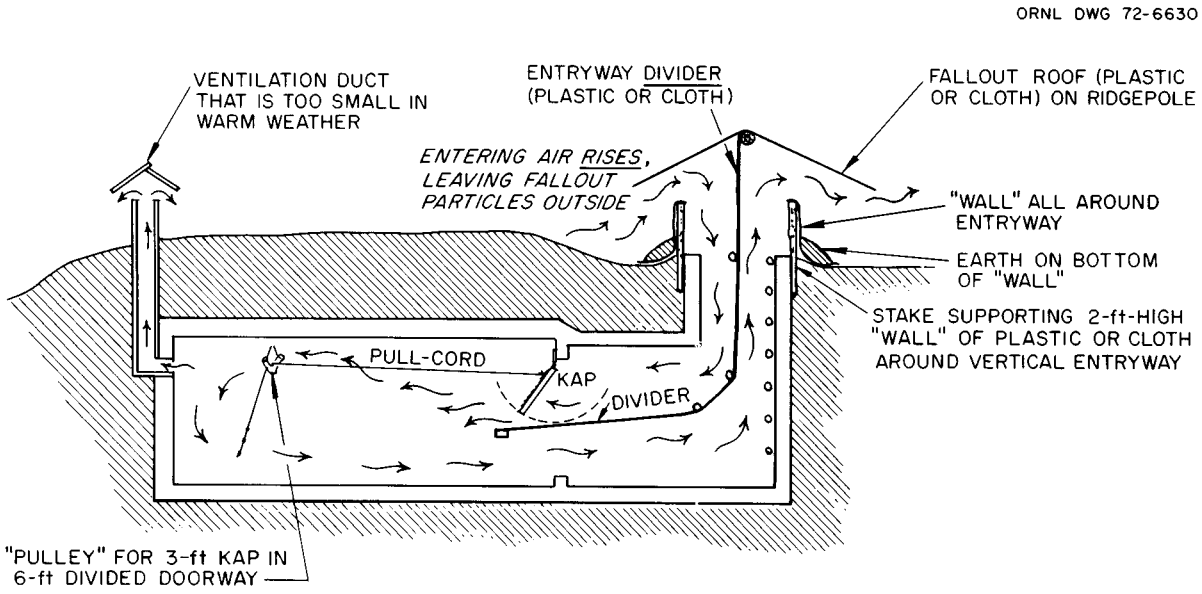


Fig. 15. Ventilating a shelter when the air-exhaust opening is too small.

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Note how the entry of fallout into a shelter can be minimized by covering the entryway with a "roof" and by forcing the slow-moving entering air to rise over an obstruction (the "wall") before it flows into the shelter. The sand-like fallout particles fall to the ground outside the "wall."

C. Adequate Distribution of Air Within the Shelter

To make sure that each shelter occupant gets a fair share of the outdoor air pumped through the shelter, **air-distribution KAPs** should be used inside most large shelters. These KAPs are used within the shelter, separate from and in addition to air-supply KAPs (see Fig. 16). Air-distribution KAPs can serve in place of both air-distribution ducts and cooling fans. For these purposes, one or more 3-ft-high KAPs hung overhead from the shelter ceiling are usually most practical. If KAPs cannot readily be hung from the ceiling, they can be supported on light frames made of boards or metal, somewhat like those used for a small child's swing.

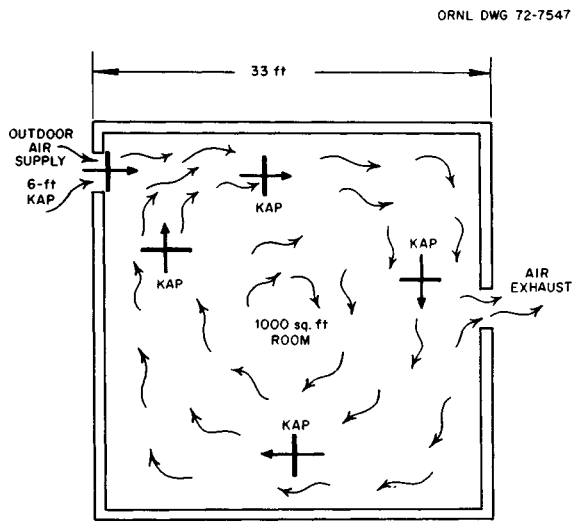


Fig. 16. The use of air-distribution KAPs.

You should make and use enough KAPs to cause air movement that can be felt in all parts of your shelter. Remember that if KAPs are installed near the floor and the shelter is fully occupied, the occupants' bodies will partially block the pumped airflow more than if the same KAPs were suspended overhead.

As a general rule, for shelters having more than about 20 occupants, provide one 3-ft air-distribution KAP for every 25 occupants. In relatively wide shelters, these interior KAPs should be positioned so that they produce an airflow that circulates around the shelter, preventing the air that is being pumped into the shelter from flowing directly to the exhaust opening. Figure 16 illustrates how four KAPs can be used in this way to distribute the air within a shelter and to fan the 100 occupants of a 1000-sq.-ft shelter room. Avoid positioning an air-distribution KAP so that it pumps air in a direction greater than a right angle turn from the direction of airflow to the location of the KAP.

D. Operation with a Pulley

A small KAP—especially one with improvised hinges or one installed at head-height or higher—can be pulled most efficiently by running its pull-cord over a pulley or over a greased homemade "pulley" such as described in Figs. 17 and 18. A pulley should be hung at approximately the same height as the hinges of the KAP, as illustrated in Fig. 15. To make

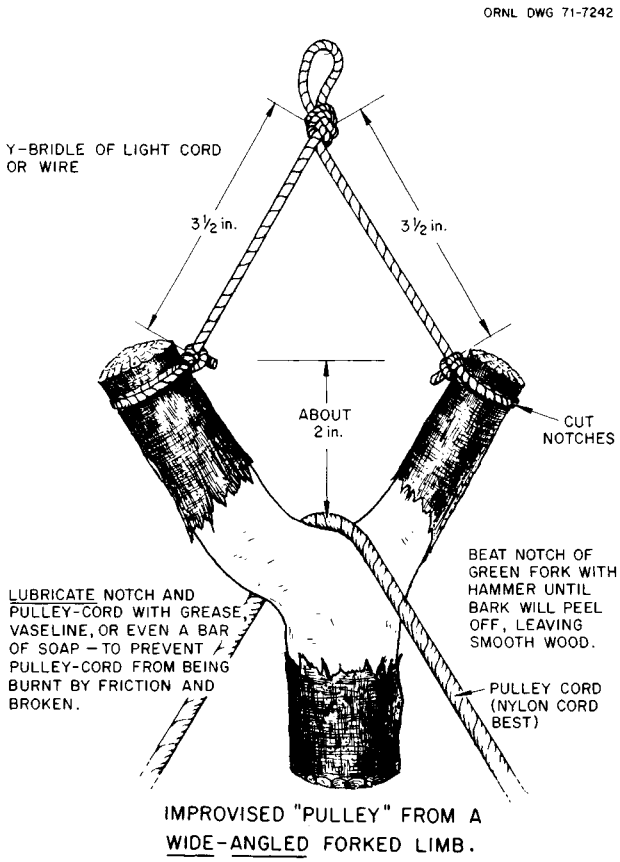


Fig. 17.

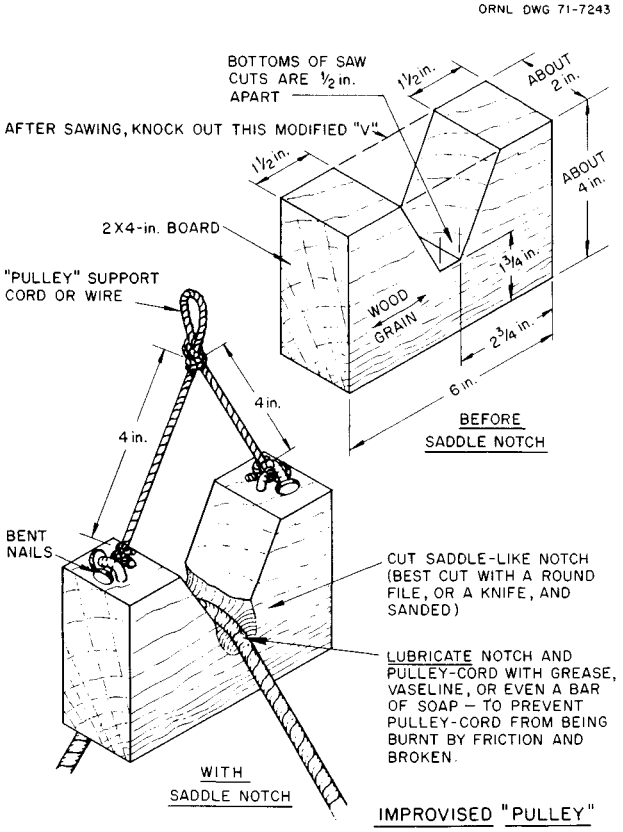


Fig. 18.

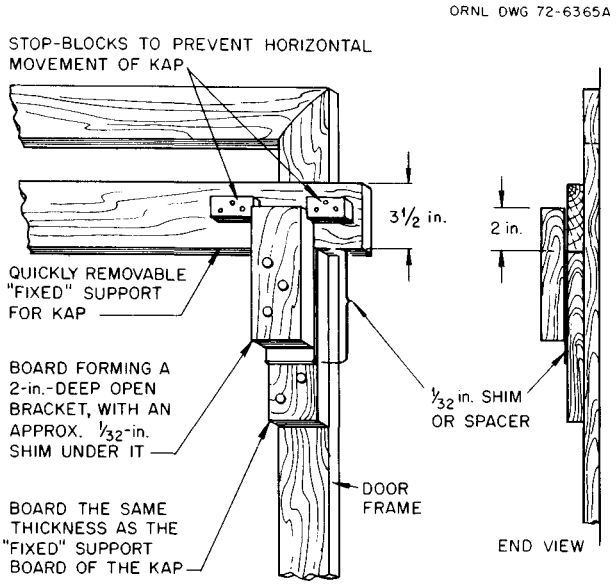


Fig. 19. Quick-removal bracket for KAP.

a comfortable hand-hold on which to pull downward, tie two or three overhand knots in a strip of cloth on the end of the pull-cord.

(Such a "pulley" can also be used to operate a bail-bucket to remove water or wastes from some shelters, without anyone having to go outside.)

E. Quick-Removal Brackets

The air-supply KAP that pumps air through your shelter is best held in its pumping position by mounting it in homemade quick-removal brackets (see Fig. 19) for the following reasons:

- A KAP provided with quick-removal brackets can be taken down easily and kept out of the way of persons passing through its doorway when it is not in use. It can be kept in a place where people are unlikely to damage it.

- By installing two sets of quick-removal brackets in opposite shelter openings, you can quickly reverse the direction in which the KAP pumps air, to take advantage of changes in the direction of natural airflow through the shelter.

- If the KAP is installed on quick-removal brackets, in an emergency a person standing beside the KAP could grasp its frame with both hands, lift it upward a few inches to detach it, and carry it out of the way—all in 3 to 5 seconds. Being able to move the KAP quickly could prevent blast winds from wrecking the pump, which might also be blown into your shelter—possibly injuring occupants. In extensive areas where fallout shelters and their occupants would survive the blast effects of typical large warheads, more than 4 seconds would elapse between the time shelter occupants would see the extremely bright light from the explosion and the arrival of a blast wave strong enough to wreck a KAP or other pumps left exposed in a ventilation opening.

Note in Fig. 19 that the KAP's "fixed" support-board (a $3^1/_2$-in.-wide board to which its hinges are attached) is held in a bracket only 2 inches deep. To prevent too tight a fit in the bracket, be sure to place a $^1/_{32}$-in. shim or spacer (the cardboard back of a writing tablet will do) between two boards of the bracket, as illustrated. Also, make spaces about $^1/_{16}$ inches wide between the lower inner corners of the stop-blocks and the sides of the outer board. To prevent your hands from being cut, you should put tape over the exposed ends of wires near the frame's outer edges of a KAP that you want to be able to remove rapidly.

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In a small expedient shelter, a small KAP can be quickly jerked loose if its "fixed" support-board is attached to the roof with only a few small nails.

VI. OPERATION AND MAINTENANCE

A. Pumping

Operate your 3-foot KAP by pulling it with an easy, swinging motion of your arm. To pump the maximum volume of air, you should pull the KAP toward you until its frame swings out to an almost-horizontal position. Then quickly move your hand so that the pull-cord is kept **slack during the entire, free-swinging return stroke.** Figure 24 in Section VIII, LARGE KAPs, illustrates this necessary motion.

Be sure to provide a comfortable hand-hold on the pull-cord (see Fig. 14). Blisters can be serious under unsanitary conditions.

To pull a KAP via an overhead pulley with minimum effort, sit down and pull as if you were tolling a bell—except that you should raise your hand quickly with the return stroke and keep it raised long enough so that the pull-cord remains slack during the entire return stroke. Or, if the pulley is not overhead, operate the KAP by swinging your extended arm back and forth from the shoulder.

B. Placement to Take Advantage of the Natural Direction of Air Flow

A KAP can pump more air into a shelter if it is installed so that it pumps air through the shelter in the direction in which the air naturally flows. Since this direction can be reversed by a wind change outdoors, it is desirable to provide a way to quickly remove your pump and reposition it so that air can be pumped in the opposite direction. This can be done in several ways, including making one set of quick-removal brackets for one air opening and a second set for the other.

C. Maintenance

To operate your KAP efficiently, keep the flaps in good repair and make sure that there is the minimum practical area of open spaces in and around the KAP through which air can flow back around the pump frame, opposite to the pumped direction. So keep at least some extra flap material in your shelter, along with some extra tape and the few tools you may need to make repairs.

VII. NARROW KAPs AND SMALL KAPs

A. Narrow KAPs

To swing efficiently in an entrance or emergency exit of an expedient trench shelter that is 22 in. wide, a KAP is best made 20 in. wide and 36 in. high. One of less height is not as efficient as a 36-in.-high model and has to be pulled uncomfortably fast. So, when ventilation openings can be selected or made at least 38 in. high, make your pump 36 in. high.

In a narrow trench shelter, it is best to have the pull-cord run the full length of the trench, along the trench wall that occupants will face when sitting. Then each occupant can take a turn pulling the pump without having to change seats.

Good metal hinges on a narrow KAP allow it to swing properly if pulled with the pull-cord attached to **one side** of the frame. (Pumps with improvised hinges and large pumps must be pulled from a connection point on their center vertical brace to make them swing properly.) Therefore, if you have small metal hinges and need a KAP no wider than 20 inches, build a rectangular frame **without** a vertical center brace. Make two pull-cord attachment points, one on each side of the frame and each 9 inches below the top of the frame. (For a small KAP, a satisfactory attachment point can readily be made by driving two nails so that their heads cross, and wiring them together.) Then if a change in wind direction outside causes the direction of natural air flow in the trench to become opposite to the direction in which air is being pumped, you can move your KAP to the opening at the other end of the trench. The pull-cord can easily be connected to the other side of the frame, and convenient pumping can be resumed quickly.

So that the horizontal support board can be nailed easily to the roofing poles or boards of an entry trench, it is best to use cabinet hinges. Screw them onto an **edge** of the support board, in the UNusual, OUT-OF-LINE POSITION shown in Fig. 20. This hinge connection allows the pump to swing a full 180 degrees. To facilitate moving the horizontal support board, connect it to the roof with a few small nails, so that it can be pulled loose easily and quickly.

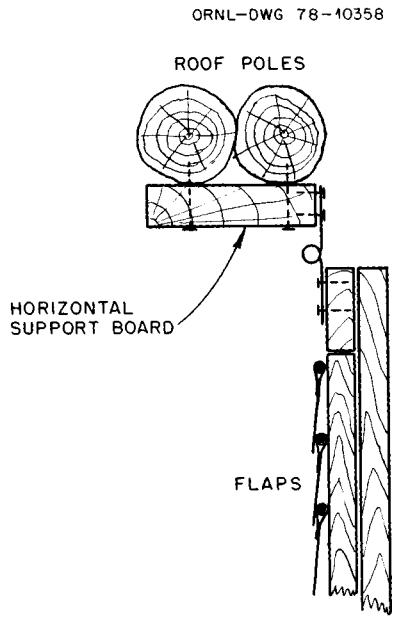


Fig. 20.

B. Small KAPs

If the only available opening in which a KAP can be installed is small, build a KAP to fit it. Use narrower boards to make the frame and make the flaps of thinner material, such as the polyethylene of large plastic trash bags. For pumps 24 inches or less in height, make the finished flaps only $3^1/_2$ inches wide and space their pivot-wires 3 inches apart. The flaps should overlap no more than $^1/_2$ inch. A KAP 24 inches high will pump enough outdoor air for only a few people, except in cold weather.

Small, yet efficient KAPs can be made even if the only materials available are straight sticks about $1^1/_4$ inches in diameter, strips of cloth to tie the frame together and to make the hinges and the pull cord, polyethylene film from large trash bags for the flaps, freezer or duct tape (or needle and thread) to make the flap hems, coat hanger wire or string for the pivot-wire, and string or ordinary thread for the flap-stops. A sharp knife is the only essential tool. Figure 21 shows a way to easily tie sticks securely together and to attach strings or threads for stop-flaps, when small nails and tacks are not available. The flap-stop strings or threads should be secured by wrapping them several times around each stick to which they are attached, so they will be gripped by the out-of-line knife cuts.

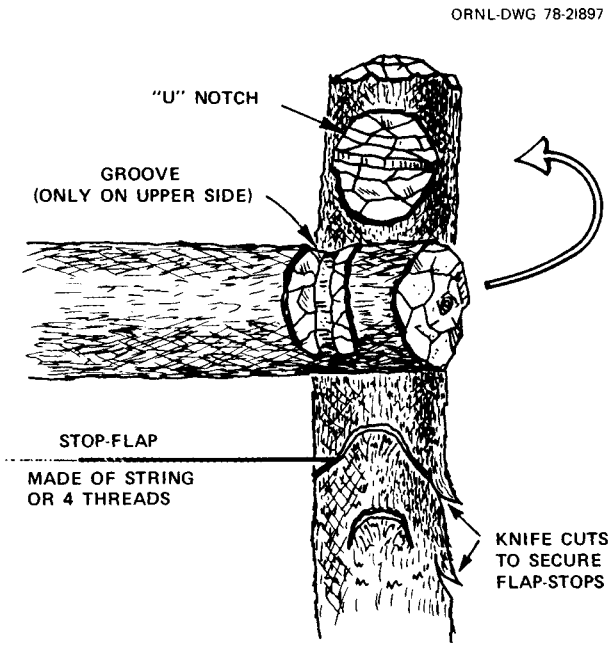


Fig. 21. Sticks ready to be tied together to make a KAP frame.

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VIII. LARGE KAPs

A. Construction

A 6-ft-high by 29-in.-wide model can be constructed in the same way as a 3-ft model—except that it should have both horizontal and vertical center braces (1 × 2-in. boards are best). To increase the strength of a 6-ft KAP, all parts of its double-thickness frame and its vertical center brace should be made of two thicknesses of 1 × 2-in. softwood boards, securely held together with clinched nails. Also, to increase the distance that the pump will swing back by itself during its return stroke, it is worthwhile to attach a 6-ft piece of 1 × 2-in. board (not illustrated) to the back of each side of the frame. Do NOT attach weights to the bottom of the frame; this would slow down the pumping rate.

This 6-ft-high pump requires 18 flaps, each the same size as those of the 36-in.-high KAP. The flaps on the lower part of a large KAP must withstand hard use. If $^1/_2$-in.-wide strips of tape are attached along the bottom and side edges of these lower flaps, then even flaps made of ordinary 4-mil polyethylene will remain serviceable for over 1000 hours of pumping. However, the **lower** flaps of large KAPs can advantageously be made of 6-mil polyethylene. The width and spacing of all flaps should be the same as those of the 36-in.-high model.

The pull-cord should be attached to the vertical center brace of a 6-ft KAP about $16^1/_2$ in. below the hinge line. A $^3/_{16}$-in. nylon cord is ideal.

To adequately ventilate and cool very large and crowded shelters in buildings, mines, or caves, KAPs larger than 72 × 29 in. should be used. You can take better advantage of large doorways, elevator shaft openings, etc., by "tailor-making" each large air-supply KAP to the size of its opening—that is, by making it as large as is practical. The frame and brace members should be appropriately strengthened, and one or more "Y" bridles should be provided, as described in the section below. A 7-ft-high × $5^1/_2$-ft-wide KAP, with a $^1/_4$-in.-diameter pull-cord attached 18 in. below its hinge line, and with two "Y" bridles for its two operators, pumped air at the rate of over 11,000 cubic ft per minute through a large basement shelter during tests.

To make a durable connection of the pull-cord to the center vertical brace: (1) Attach a wire loop (Fig. 22) about $16^1/_2$ in. below the hinge line. This loop can be made of coat hanger wire and should go around the center vertical brace. This fixed loop should be kept from slipping on the center brace by bending four 6-penny nails over it in front as illustrated, and two smaller nails in back. (2) Make a free-turning, triple-wire loop connected to the fixed loop. (3) Cover part of the free-turning loop with tape and tie the pull-cord to this loop. Tie the pull-cord tightly over the taped part.

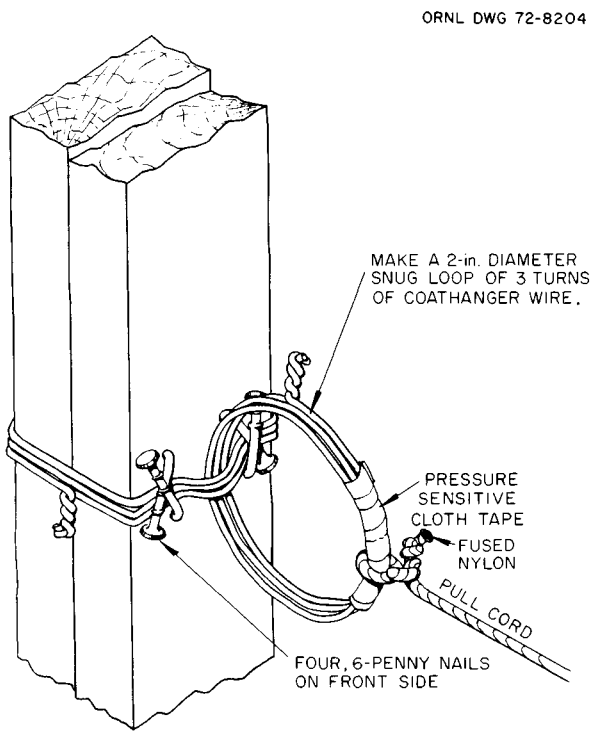


Fig. 22.

B. Operation of Larger KAPs

A larger KAP can be pulled most easily by providing it with a "Y" bridle (see Fig. 23) attached to the end of its pull-cord.

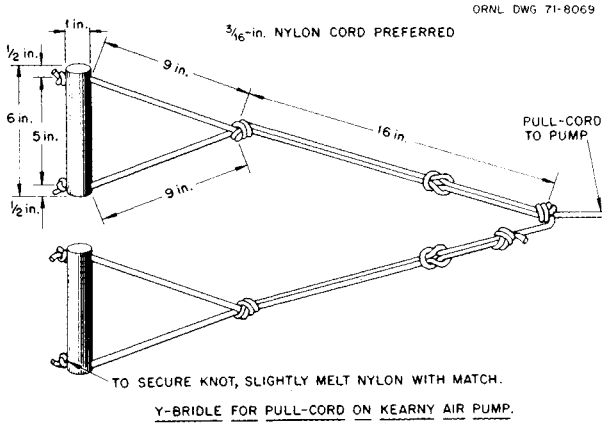


Fig. 23. Y-bridle for pull-cord on KAP.

A man of average size and strength can operate a 6 ft × 29 in. KAP by himself, pumping over 4000 cubic feet per minute through a typical large shelter without working hard; tests have shown that he must deliver only about $^1/_{20}$ of a horsepower. However, most people prefer to work in pairs when pulling a 6-ft KAP equipped with a "Y" bridle, when pumping over 3000 cfm.

To pump the maximum volume of air with minimum effort, study Fig. 24 and follow the instructions given below for operating a large KAP.

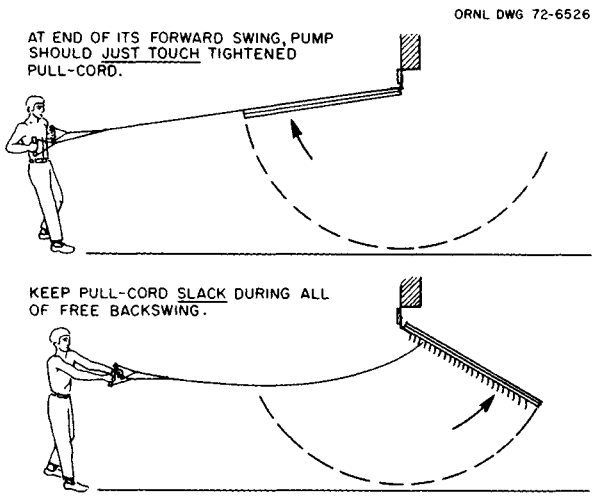


Fig. 24.

1. Gradually start the pump swinging back and forth, moving your arms and body as illustrated and **pulling mostly with your legs and body.**

2. Stand at such a distance from the pump that you can pull the pump toward you until the forward-swinging pump **just touches the tightly stretched pull-cord**—and at such a distance that you can keep the pull-cord **slack** during the whole of the pump's free backswing.

3. To be sure you do not reduce the amount of air pumped, rapidly move your arms forward **as soon as the forward-swinging pump touches the tightened pull-cord.** Hold your arms forward until the pump again starts to swing toward you.

IX. SOLUTIONS TO SPECIAL PROBLEMS

A. Increasing the Usefulness of Shelters by Supplying 40 cfm per Planned Occupant

If a shelter is fully occupied for days during hot weather and is cooled both day and night by pumping through it and distributing at least 40 cubic feet per minute of outdoor air for each occupant—more than is required to maintain tolerable temperatures at night—these advantages result:

- The shelter occupants will be exposed to effective temperatures less than 2° F higher than the current effective temperatures outdoors, and at night will get relief from extreme heat.

- The floors, walls, etc. of a shelter so ventilated will be cooled at night to temperatures well below daytime temperatures. Therefore, during the day a considerable fraction of the occupants' body heat will flow into the floors, walls, and other parts of the shelter and less body heat will have to be carried out by the exhaust air during the hottest hours of the day. Thus daytime temperatures will be reduced.

- Since the shelter occupants will be cooler and will sweat less, especially at night, they will need less water than they would require if the shelter were ventilated at a rate of less than 40 cfm per occupant. (If the outdoor air is very hot and desert-dry, it usually is better to supply less than 40 cfm per occupant during the hottest hours of the day.)

- If the shelter were to be endangered by the entry of outside smoke, carbon monoxide or other poisonous gases, or heavy descending fallout under windy conditions, ventilation of the shelter could be temporarily restricted or stopped for a longer period than would be practical if the shelter itself were warmer at the beginning of such a crisis period.

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- The shelter could be occupied beyond its rated capacity without problems caused by overcrowding becoming as serious as would be the case if smaller-capacity air pumps were to be installed and used.

B. Pre-Cooling Shelters

If the shelter itself is cooler than the occupants, more of the body heat of occupants can flow into its cool walls, ceiling, and floor. Therefore, it would be advantageous to pre-cool a shelter that may soon be occupied, especially during hot weather. KAPs (or other air pumps or fans) can be used to pre-cool a shelter by forcing the maximum volume of cooling outdoor air through the shelter and by distributing it within the shelter. A shelter should be pre-cooled at all times when the air temperature outdoors is lower than the air temperature inside the shelter. Then, if the pre-cooled shelter is used, the occupants will be kept cooler at a given rate of ventilation than if the shelter had not been pre-cooled, because the air will not have to carry all of their body heat out of the shelter.

C. Increasing the Effectiveness of a KAP

If you want to increase the volume of air that a KAP with good metal hinges can force through a shelter, install side baffles (see Fig. 25). Side baffles should be rigidly fixed to form two stationary "walls," one on each side of the swinging pump frame. They can be made of plywood, boards, doors, table tops, or even well-braced plastic. A space or clearance of $\frac{1}{2}$ to 1 in. should be maintained between the inner side of each baffle and the outer side of the swinging frame.

By installing side baffles you may be able to increase the volume of air your KAP will pump by as much as 20%, if it is in good repair and the openings around it are small.

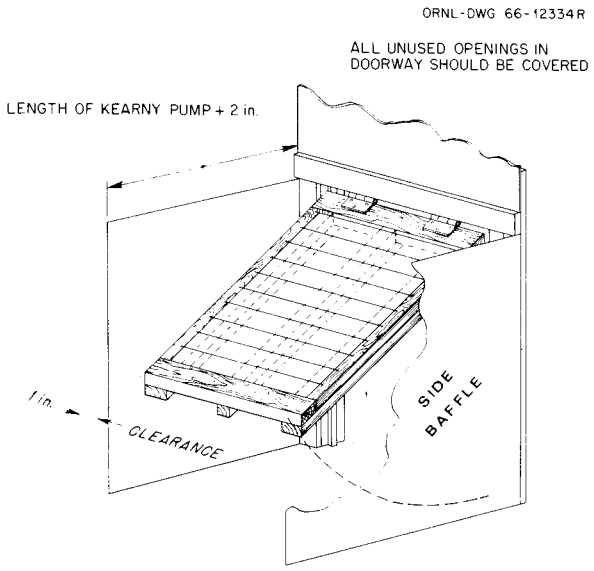


Fig. 25. Side baffles.

D. Operating a KAP as an Exhaust Pump

In some shelters, a KAP can be operated most effectively by using it as an exhaust pump. This can be done by pushing it with a push-pole attached to its center vertical brace. Push-pole operation is sometimes the best way to "suck" outdoor air into a shelter by pumping air out of the shelter in the natural direction of air flow; for example, up an elevator shaft or up a stairwell. This method is especially useful in those basement shelters in which air-intake openings are impractical for installing KAPs. This would be the case if the air-intake openings are small, exposed windows or holes broken in the ceiling of a shelter in a building.

To pump a large KAP most effectively with a push-pole, stand with your back to the KAP and grasp the push-pole with both hands. Using mostly your leg muscles, push the KAP by pulling the free end of its push-pole toward you.

Figure 26 shows an improvised, flexible connection of a push-pole attached to the center brace of a large KAP 28 in. from the top of its frame.

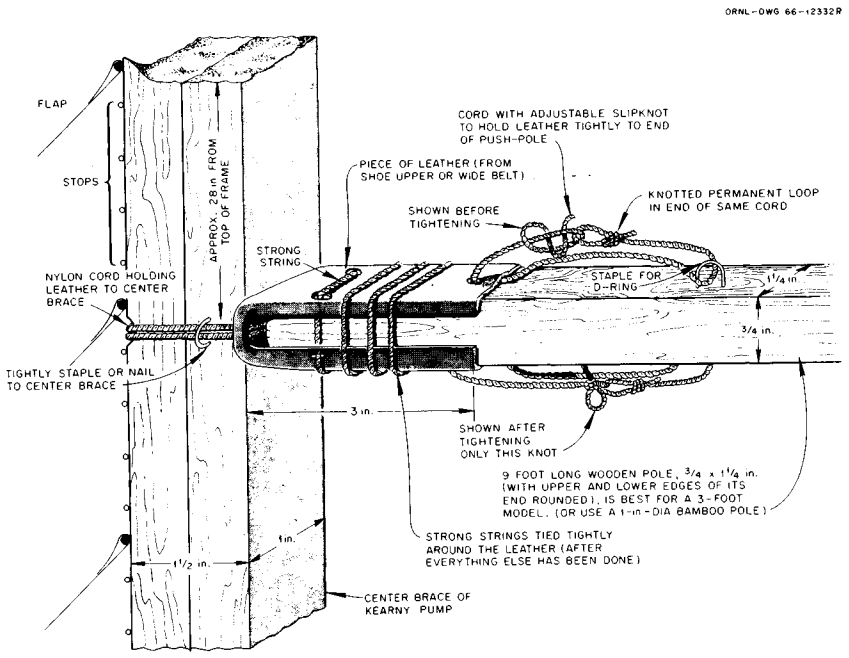


Fig. 26. Push-pole flexible connection.

E. Ventilating a Shelter with Only One Opening

Some basement rooms that may be used as shelters have only one opening, the doorway. A KAP can be used to ventilate such a shelter room if enough well-mixed and distributed air is moving just outside the doorway, or if air from outdoors can be pumped in by another KAP and made to flow in a hallway or room and pass just outside this doorway. Figure 27 indicates how to ventilate such a one-opening room by operating a 3-ft KAP as an air-intake pump in the upper part of the doorway.

Below such a doorway KAP, a "divider" 6 ft to 8 ft long can be installed. The divider permits exhaust air to flow out of the room without much of it being "sucked" back into the room by the KAP swinging above it. Plywood, reinforced heavy cardboard, or even well-braced plastic can be used to make a divider. It should be installed so that, in a possible emergency, it can be jerked out of the way in a few seconds.

When used with a divider, a 36×29 in. KAP can pump almost 1000 cubic feet of air per minute into and out of such a shelter room. Although 1000 cubic feet of well-distributed air is sufficient for several times as many as 25 shelter occupants under most temperate climate conditions, it is enough for only about 25 people in a one-entry room under exceptionally severe heat-wave conditions. Furthermore, to make it habitable for even 25 people under such conditions, the air in this room must be kept from rising more than 2°F above the temperature outdoors. This can be done using a second air-supply KAP to pump enough outdoor air through the building and in some cases also using air-distribution KAPs in spaces outside the one-entry room. The KAP in the doorway of a one-entry room should supply 40 cfm per occupant of this room.

In order to prevent any of the used, warmed, exhaust air from the one-entry room from being "sucked" by the doorway KAP back into the room, a stiffened rectangular duct can be built so as to extend the exhaust-opening (in the lower part of the doorway) several feet outside the room. Such a duct can be built of plastic supported by a frame of small boards. It can be used to discharge the exhaust air far enough away from the KAP and "downstream" in the airflow outside the one-opening room so that no exhausted air can be "sucked" back into the room.

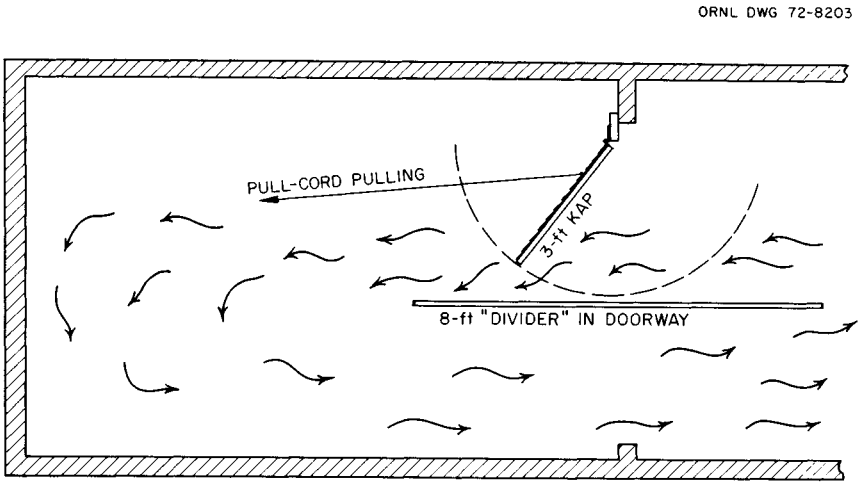


Fig. 27. Use of a "divider" to ventilate a shelter with only one opening.

F. Installing a KAP in a Steel-Framed Doorway

If you need to install a KAP in a steel-framed doorway and it is not feasible to screw or otherwise permanently connect it to the doorway, you can attach the KAP by using a few boards and some cord, as illustrated by Figs. 28 and 29. The two horizontal boards shown extending across the doorway are squeezed tightly against the two sides of the wall in which the doorway is located by tightening two loops of cord, one near each side of the doorway. One loop is illustrated. A cord is first tightened around the two horizontal boards. Then the looped cord is further tightened by binding it in the center with another cord, as illustrated.

Two large "C" clamps serve even better than two looped cords. However, secure support for a swinging KAP still requires the use of a vertical support board on each side of the doorway, as illustrated.

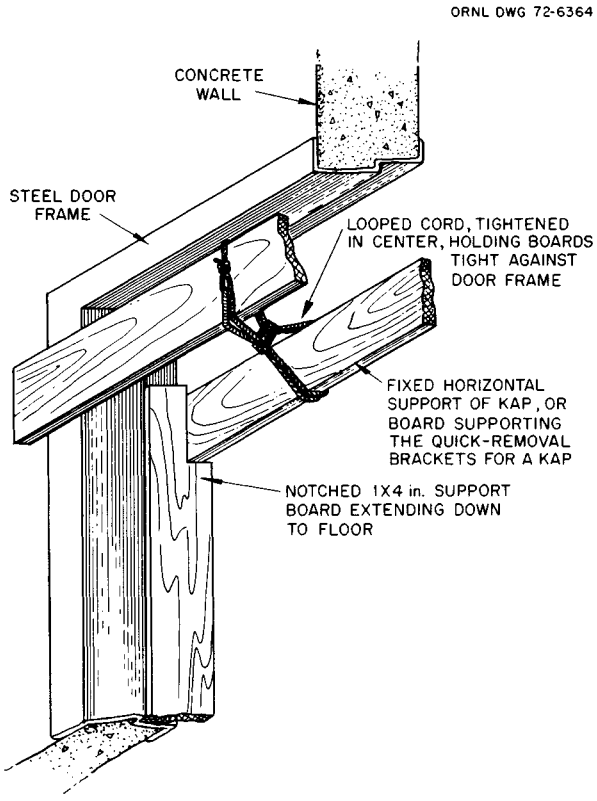


Fig. 28.

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Figure 29 shows a quick-removal bracket supported by two horizontal boards tightened across the upper part of a doorway by looped cords, as described above. Also, study Fig. 19 and its accompanying instructions.

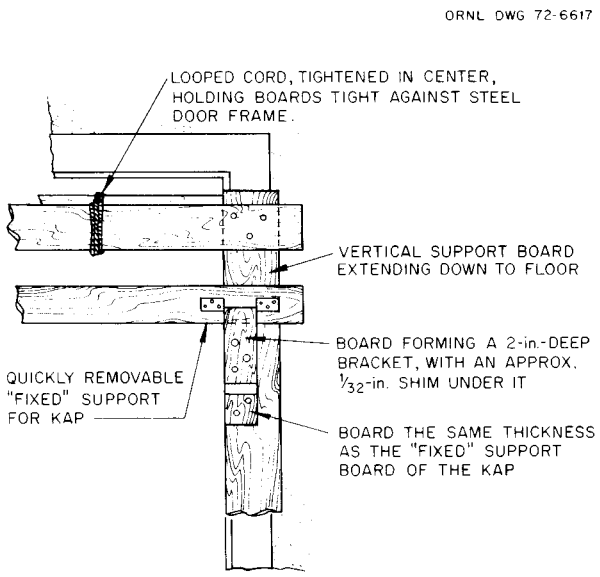


Fig. 29.

G. Building More Durable KAPs

If you are building KAPs in normal times, you may want to use materials that will make your pumps last longer, even though these materials are more difficult to obtain and are more expensive.

Durability tests have shown that the KAP parts that wear out first are the flaps and the pulleys. In 6-ft KAPs, the lower flaps are subject to hard use. Lower flaps made of 6-oz (per sq. yd), clear, nylon-reinforced, plied vinyl have lasted undamaged for over 1000 hours of full-stroke pumping, without having their edges reinforced. Lower flaps made of 6-mil nylon-reinforced polyethylene, without edge reinforcements, have lasted for 1000 hours with only minor damage.

The best pulley tested was a marine pulley such as that used on small sailboats, with a Delrin (DuPont) 2-in.-diameter wheel and $^{3}/_{16}$-in. stainless steel shaft. This pulley was undamaged after operating a 6-ft KAP for 324 hours. The pulley appeared to be good for hundreds of hours of further operation.

The best pulley-cords tested were of braided dacron or nylon.

H. Using Air Filters

To supply shelter occupants with filtered air usually would be of **much less** importance to their survival and health than to provide them with adequate volumes of outdoor air to maintain tolerable temperatures. However, filtering the entering air could prove worthwhile, provided:

- Your shelter is not in an area likely to be subjected to blast, or it is a blast shelter with blast doors and blast valves protecting everything inside.
- Work on filters is started *after* you have completed more essential work, including the building of a high-protection-factor shelter, making, installing, and testing the necessary number of KAPs, storing adequate water, making a homemade fallout meter, etc.
- You have enough low-resistance filters (such as fiberglass dust filters used in furnaces and air-conditioners) and other materials for building the necessary large, supported filter in front of your KAP.
- Your KAP can pump an adequate volume of air through the filter and shelter.
- The filter is installed so that it can be easily removed if shelter temperatures rise too high.

To prevent a filter used with a KAP from causing too great a reduction in the volume of air that the KAP can pump through your shelter, you must use **large areas of low-resistance filter material.** An example: In one ventilation test, a large basement shelter was used which had two ordinary doorways at its opposite ends. These served as its air-intake and its air-exhaust openings. A 72×29 in. KAP operating in one doorway pumped almost 5000 cubic feet per minute through the shelter. But when a filter frame holding 26 square feet of 1-in.-thick fiberglass dust filters was placed across the air-intake stairwell, the KAP could pump only about 3400 cfm through this filter and the shelter.

Chapter 6
Ventilation and Cooling of Shelters

CRITICAL IMPORTANCE

If high-protection-factor shelters or most other shelters that lack adequate forced ventilation were fully occupied for several days in warm or hot weather, they would become so hot and humid that the occupants would collapse from the heat if they were to remain inside. It is important to understand that the heat and water vapor given off by the bodies of people in a crowded, long-occupied shelter could be deadly if fallout prevents leaving the shelter.

When people enter an underground shelter or basement in the summertime, at first the air feels cool. However, if most shelters are fully occupied for a few days without adequate ventilation, the floors, walls, and ceilings, originally cool, will have absorbed about all the body heat of which they are capable. Some shelters will become dangerously hot in a few hours. Unless most of the occupants' body heat and water vapor from sweat are removed by air circulated through a typical shelter, the heat-humidity conditions will become increasingly dangerous in warm or hot weather. One of the most important nuclear war survival skills people should learn is how to keep occupied shelters adequately ventilated in all seasons and cool enough for many days of occupancy in warm or hot weather. Methods **for ventilating with homemade devices and for keeping ventilating air from carrying fallout particles into shelters are described in Appendices A and B. Instructions for Directional Fanning, the simplest means for forcing adequate volumes of air to flow through shelters, are given at the end of this chapter.**

MAKING AND USING AN EXPEDIENT AIR PUMP

The best expedient way to maintain livable conditions in a shelter, especially in hot weather, is to make and use a large-volume shelter-ventilating pump. Field tests have proved that average Americans can build the expedient air pump described in Appendix B in a few hours, with inexpensive materials found in most households.

This simple pump was invented in 1962 by the author. I called it a Punkah-Pump, because its hand-pulled operation is somewhat like that of an ancient fan called a "punkah", still used by some primitive peoples in hot countries. (Unlike the punkah, however, this air pump can force air to move in a desired direction and is a true pump.) It was named the Kearny Air Pump (KAP) by the Office of Civil Defense following tests of various models by Stanford Research Institute, the Protective Structures Development Center, and General American Transportation Company. These tests confirmed findings first made at Oak Ridge National Laboratory regarding the advantages of the KAP both as a manually operated pump for forcing large volumes of outdoor air through shelters and as a device for distributing air within shelters and fanning the occupants. See Fig. 6.1.

The air pump instructions given in Appendix B are the result of having scores of families and pairs of untrained individuals, including children, build and use this air pump. They were guided by successively improved versions of these detailed, written instructions, that include many illustrations (see Appendix B). Some people who are experienced at building things will find these instructions unnecessarily long and detailed. However, shelter-building experiments have shown that the physically stronger individuals, usually the more experienced builders, should do more of the hard, manual work when shelters are built, and that those less experienced at building should do the lighter work—including making shelter-ventilating pumps. These detailed, step-by-step instructions have enabled people who never



Fig. 6.1. A 6-foot KAP tested for durability at Oak Ridge. After 1000 hours of operation during which it pumped air through a room at a rate of 4000 cubic feet per minute (4000 cfm), there were only minor tears in the plastic flaps.



Fig. 6.2. Behind the girl is the homemade air pump that made it possible for a family of six to live in a crowded trench shelter for more than three days. Outside the temperature rose to 93° F.

before had attempted to build a novel device of any kind to make serviceable air pumps.

(The air pump instructions given in Appendix B repeat some information in this chapter. This repetition is included both to help the reader when he starts to build an air pump and to increase the chances of the best available complete instructions being given to local newspapers during some future crisis. The instructions given in this book could be photographed, reproduced, and mass-distributed by newspapers.)

Figure 6.2 shows (behind the girl) a 20-inch-wide by 36-inch-high KAP installed in the entry trench of a trench shelter. The father of the Utah family described earlier had made this simple pump at home, using only materials and tools found in many homes—as described in Appendix B. He carried the pump on top of his car to the shelter-building site. The pendulum-like, flap-valve pump was swung from two cabinet hinges (not shown) screwed onto a board. The board was nailed to roof poles of the narrow entry trench extending behind the girl in the photograph. The pull-cord was attached to the pump frame below its hinged top and extended along one trench wall for the whole length of the shelter. Any one of the six occupants could pull this cord and easily pump as much as 300 cubic feet per minute of outdoor air through the shelter and through the insect screens over both its entrances. (Without these screens, the numerous mosquitoes in this irrigated area would have made the family's shelter stay very unpleasant.)

During the 77 hours that the family continuously occupied their narrow, covered trench, the temperatures outside rose as high as 93° F. Without the air pump, the six occupants would have been driven from their shelter by unbearable temperature-humidity conditions during the day.[8]

The photo in Fig. 6.2 also shows how the air pump hung when not being operated, partially blocking the entry trench and causing a "chimney effect" flow of air at night. There was a 10-inch space between the air pump and the trench floor, and the resulting flow of air maintained adequate ventilation in the cool of the desert night, when outdoor temperatures dropped as low as 45° F. Cool outdoor air flowed down into the entry and under the motionless air pump, replacing the body-warmed air inside the shelter. The entering cool air continuously

forced the warm air out of the shelter room at ceiling height through the emergency crawlway-exhaust trench at the other end. When the weather is cool, a piece of plastic or tightly woven cloth could be hung in the doorway of a well designed, narrow shelter, to cause a flow of fresh air in the same manner.

Numerous shelter occupancy tests have proved that modern Americans can live for weeks in an adequately cooled shelter with only 10 square feet of floor space per person.[13] Other tests, such as one conducted by the Navy near Washington, D.C. during an abnormally cool two weeks in August, 1962, have shown that conditions can become difficult even when summertime outdoor air is being pumped through a long-occupied shelter at the rate of 12 cubic feet per minute, per person.[14,15] This is four times the *minimum* ventilation rate for each occupant specified by the Federal Emergency Management Agency (FEMA) for American shelters: 3 cubic feet per minute (3 cfm). Three cfm is about three times the supply of outdoor air needed to keep healthy people from having headaches as a result of exhaled carbon dioxide. In hot, humid weather, much more outdoor air than 12 cfm per person must be supplied to a crowded, long-occupied shelter, as will be described in the following section and in Appendix B.

MAINTAINING ENDURABLE SHELTER CONDITIONS IN HOT WEATHER

The Navy test mentioned above showed how much modern Americans who are accustomed to air conditioning could learn from jungle natives about keeping cool and healthy by skillfully using hot, humid, outdoor air. While working in jungles from the Amazon to Burma, I observed the methods used by the natives to avoid unhealthful conditions like those experienced in the Navy shelter, which was ventilated in a conventional American manner. These jungle methods include the first five of the six cooling methods listed in this section. During 24 years of civil defense research, my colleagues and I have improved upon the cooling methods of jungle people, primarily by the invention and thorough field-testing of the homemade KAP described in Appendix B, and of the Directional Fans covered by the instructions at the end of this chapter.

Even during a heat wave in a hot part of the United States, endurable conditions can be maintained in a fully occupied, belowground shelter with this simple pump, if the test-proven requirements listed below are ALL met.

Most basement shelters and many aboveground shelters also can be kept at livable temperatures in hot weather if the cooling methods listed below are ALL followed:

- Supply enough air to carry away all the shelter occupants' body heat without raising the "effective temperature" of the air at the exhaust end of the shelter by more than 2°F. The "effective temperature" of the air to which a person is exposed is equivalent to the temperature of air at 100% relative humidity that causes the same sensation of warmth or cold. "Effective temperature" combines the effects of the temperature of the air, its relative humidity, and its movement. An ordinary thermometer does not measure effective temperature. In occupancy tests of crowded shelters when the supply of outdoor air was hot and dry, shelter occupants have been surprised to find that they felt hottest at the air-exhaust end of their shelter, where the temperature reading was lower than at the air-intake end. Their sweaty bodies had acted as evaporative air coolers, but their body heat had raised the effective temperature, a reliable indicator of heat stress. If 40 cubic feet per minute (40 cfm) per person of outdoor air is supplied and properly distributed, then (even if the outdoor air is at a temperature which is typical of the hottest hours during a heat wave in a hot, humid area of the United States) the effective temperature of the shelter air will be increased no more than 2°F by the shelter occupants' body heat and water vapor. Except for a relatively few sick people dependent on air conditioning, anyone could endure air that has an effective temperature only 2°F higher than that of the air outdoors.

(There are exceptions to this ventilation requirement when the ceiling or walls of basement or aboveground shelters in buildings are heated by the sun to levels higher than skin temperature. In such shelters, more than 40 cfm of outdoor air per occupant must be supplied. However, if a shelter is covered by at least two feet of earth, it will be so well insulated that its ceiling and walls will not get hot enough to heat the occupants.)

- Move the air gently, so as not to raise its temperature. In the aforementioned Navy test, a high speed, electric ventilating pump and the frictional resistance of pipes and filters raised the temperature of the air supplied to the shelter by 3°F. Under extreme heat wave conditions, an air supply 3°F hotter than outdoor air could be disastrous—especially if considerably less than 40 cfm per occupant is supplied, and body heat raises the air temperature several additional degrees.

- Distribute the air quite evenly throughout the shelter. In a trench shelter, where air is pumped in at one end and flows out the other, good distribution is assured. In larger shelters, such as basements, ventilating air will move from the air-supply opening straight to the air-exhaust opening. Persons out of this air stream will not be adequately cooled. By using one or more additional, smaller KAPs (also described in Appendix B), fresh air can be distributed easily throughout large shelter rooms, and the occupants will be gently fanned.

- Provide occupants with adequate drinking water and salt. In extremely hot weather, this means 4 quarts of water per day per person and 1 tablespoon (10 grams) of salt, including the salt in food.

- Wear as few clothes as practical. When the skin is bare, moving air can evaporate sweat more efficiently for effective cooling. Air movement can keep bare skin drier, and therefore less susceptible to heat rash and skin infections. In the inadequately ventilated Navy test shelter, 34 of the 99 initially healthy young men had heat rash and 23 had more serious skin complaints at the end of their sweaty two-week confinement, although their overall physical condition had not deteriorated.[15] However, at sick call every day all of these Navy test subjects with skin complaints were treated by medical corpsmen. In a nuclear war, very few shelter occupants would have medicines to treat skin diseases and infections, that if not taken care of usually worsen rapidly under continuously hot, humid conditions. Simple means for preventing skin diseases and infections—means proved very effective by jungle natives and by our best trained jungle infantrymen in World War II — are described in the Prevention of Skin Diseases section of Chapter 12.

- Keep pumping about 40 cfm of air per person through the shelter both day and night during hot weather, so that the occupants and the shelter itself will be cooled off at night. In the Navy test, the ventilation rate of 7 to 12 cfm was not high enough to give occupants the partial relief from heat and sweating that people normally get at night.[15] In a National Academy of Sciences meeting on protective shelters, an authority stated: "Laboratory experiments and field investigations have shown that healthy persons at rest can tolerate daily exposures to ETs [effective temperatures] up to 90° F, provided they can get a good night's sleep in a cooler environment."[14] An effective temperature 90° F is higher than the highest outdoor effective temperature during a heatwave in the South or in American deserts.

ADEQUATE VENTILATION IN COLD WEATHER

In freezing weather, a belowground shelter covered with damp earth may continue to absorb almost all of its occupants' body heat for many days and stay unpleasantly cold. In one winter test of such a fully occupied shelter, the temperature of the humid air in the shelter remained around 50° F.[16] Under such conditions, shelter occupants should continue to ventilate their shelter adequately, to avoid the following conditions:

- A dangerous buildup of carbon dioxide from exhaled breath, the first symptoms of which are headaches and deeper breathing.

- Headaches from the carbon monoxide produced by smoking. When the ventilation rate is low, smoking should not be permitted, even near the exhaust opening.

- Headaches, collapse, or death due to carbon monoxide from open fires or gasoline lanterns that release gases into the shelter air.

NATURAL VENTILATION

Enough air usually will be blown through an aboveground shelter if sufficiently large openings are provided on opposite sides and if there is any breeze. But if the weather is warm and still and the shelter crowded, the temperature-humidity conditions soon can become unbearable.

Adequate natural ventilation for belowground shelters is more difficult. Even if there is a light breeze, not much air will make a right-angle turn and go down a vertical entry, make another right-angle turn, and then flow through a trench or other shelter partially obscured by people and supplies.

In cool weather, occupants' body heat will warm the shelter air and make it lighter than the outdoor air. If a chimney-like opening or vent-duct is provided in the ceiling, the warmed, lighter air will flow upward and out of the shelter, provided an adequate air-intake vent is open near the floor. An Eskimo igloo is an excellent example of how very small ventilation openings, skillfully located in the ceiling and at floor level, make it possible in cold weather for chimney-type natural ventilation to supply the 1 cfm per person of outdoor air needed to prevent exhaled carbon dioxide from becoming dangerously concentrated.

In warm weather, chimney-type natural ventilation usually is inadequate for most high-protection-factor shelters that are fully occupied for days. And in hot weather, when as much as 40 cfm per occupant is required, body-warmed shelter air is no lighter than the outdoor air. Chimney-type ventilation fails completely under these conditions.

SHELTER VENTILATION WITHOUT FILTERS

Numerous tests have shown that the hazards from fallout particles carried into shelters by unfiltered ventilating air are minor compared to the dangers from inadequate ventilation. A 1962 summary of the official standards for ventilating systems of fallout shelters stated: "Air filters are not essential for small (family size) shelters . . . "[17] More recent findings have led to the same conclusion for large fallout shelters. A 1973 report by the Subcommittee on Fallout of the National Academy of Sciences on the radioiodine inhalation problem stated this conclusion: "The opinion of the Subcommittee is that inhalation is far less of a threat than ingestion [eating or drinking], and does not justify countermeasures such as filters in the ventilating systems of shelters."[18]

Recommendations such as those above realistically face the fact that, if we suffer a nuclear attack, the vast majority of Americans will have only the fallout protection given by buildings and some expedient shelters. Consequently, how best to use available resources must be the primary consideration when planning for protection against the worst dangers of a nuclear attack; relatively minor hazards may have to be accepted. For unprepared people, inhalation of fallout particles would be a minor danger compared to being forced out of a shelter because of dangerously inadequate ventilation.

The most dangerous fallout particles are those deposited on the ground within the first few hours after the explosion that produces them. Typically, these "hot" particles would be so large and fast-falling that they would not be carried into expedient shelters equipped with low-velocity air intake openings, such as those described in this book. Nor would these most dangerous "hot" fallout particles be "sucked" into gooseneck air-intake pipes, or other properly designed air-intake openings of a permanent shelter.

For most shelters built or improved hurriedly during a crisis it will be impractical to provide filtered air. The Car-Over-Trench Shelter pictured in Fig. 6.3 points up the overriding need for pumped air for occupants of crowded shelters during warm or hot weather. This simple shelter provides fallout protection about four times as effective as that given by a typical home basement. After the car was driven over the trench, earth was shoveled into the car and its trunk and on top of its hood. At one end was a combined crawlway entrance/air intake opening, at the other end, a 1-foot-square air exhaust opening. Each opening was covered by a small awning. To keep loose shielding earth from running under the car and into the trench, the upper edges of 5-foot-wide strips of polyethylene film first were attached with duct tape to the sides and ends of the car, about 2 feet above the ground. Then earth was piled onto the parts of the film strips that were lying on the ground, to secure them. Finally, earth was piled against the vertical parts of the attached film strips.



Fig. 6.3. Pulling a Small, Stick-Frame KAP to Keep Temperatures Endurable for Occupants of a Car-Over-Trench Shelter in Warm Weather. Enough air also can be supplied with a small Directional Fan, although more laboriously.

(Placing earth rolls — see page 150 — around the sides of an earth-loaded car provides better, more secure side shielding, but requires more materials and work.)

INHALATION DANGERS

Only extremely small fallout particles can reach the lungs. The human nose and other air passages " . . . can filter out almost all particles 10 micrometers [10 microns] [or larger] in diameter, and about 95 percent of those exceeding 5 micrometers." (See reference 6, page 599.) Five micrometers equal 5 millionths of a meter, or 5 thousandths of a millimeter.

Using a dust mask or breathing through cloth would be helpful to keep from inhaling larger "hot" fallout particles which may cause beta burns in noses, sinuses, and bronchial tubes. Many such retained particles may be swallowed when cleared from one's air passageways by the body's natural protective processes.

As shown below in Fig. 6.4, a relatively "large" particle — 40 microns (40 μm) in diameter, spherical, and with the sand-like density of most fallout particles — falls about 1300 feet in 8 hours. (A dark-colored particle 40 microns in diameter is about as small a speck as most people can see with the naked eye.) Most 40-μm-diameter fallout particles would take a

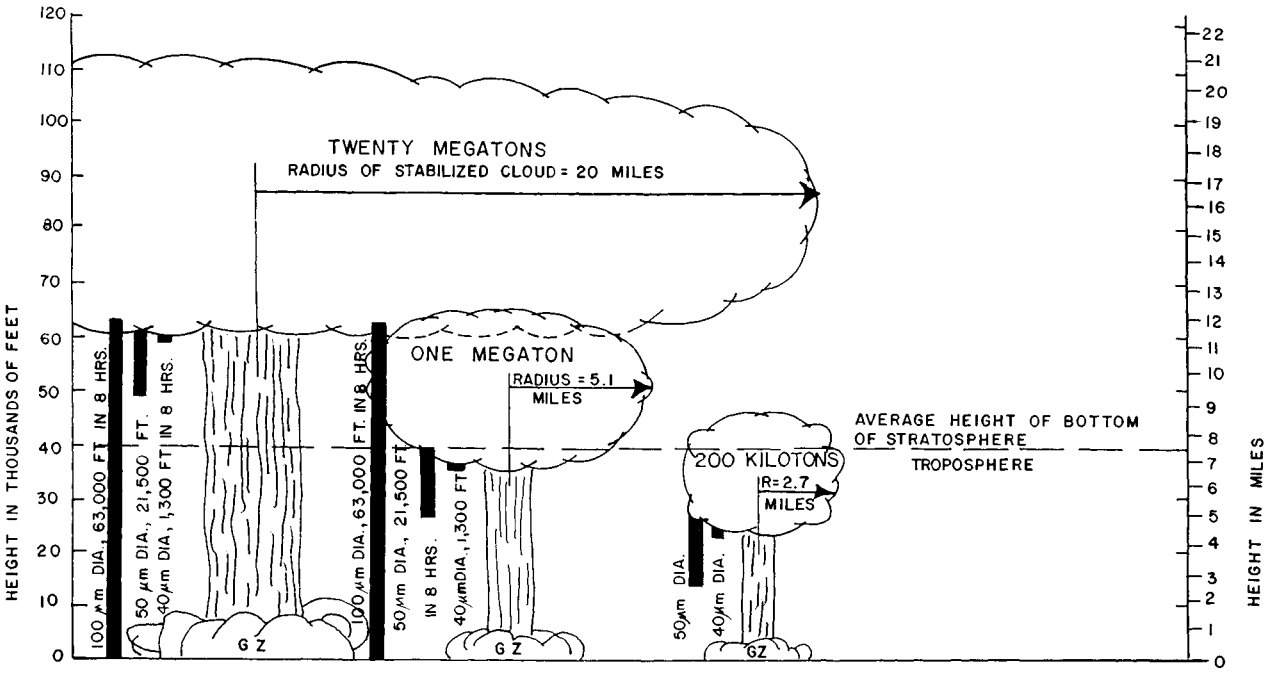


Fig. 6.4. Stabilized Radioactive Fallout Clouds Shown a Few Minutes After the Explosions, with distances that spherical fallout particles having diameters of 40, 50, and 100 microns fall in 8 hours.[6]

few days to fall from the cloud of a one-megaton explosion down far enough into the troposphere to be occasionally scavenged and promptly brought to earth by rain or snow while still very radioactive. In 1987, however, most of the thousands of deployed Soviet ICBM warheads are 550 kilotons or smaller. (See *Jane's Weapon Systems, 1987-88.*) The stabilized clouds of such explosions would be mostly in the troposphere, and some of even the tiniest particles — those small enough to be breathed into one's lungs — would be promptly scavenged and deposited in scattered "hot spots." Fortunately, most of the very small and tiniest fallout particles would not be deposited for days to months, by which time radioactive decay would have made them much less dangerous. Breathing tiny radioactive particles into one's lungs would constitute a minor health hazard compared to other dangers that would afflict an unprepared people subjected to a large scale nuclear attack.

SCAVENGING OF RADIOACTIVE PARTICLES

Scavenging is most effective below about 30,000 feet, the maximum height of most rain and snow clouds. See Fig. 6.4. Because the Soviets have deployed thousands of ICBMs with warheads of "only" 100 to 550 kilotons, Americans face increased dangers from very radioactive particles scavenged by rain-outs or snow-outs. The resultant "hot spots" of fallout heavy enough to kill unsheltered people in a few weeks could be scattered even hundreds of miles downwind from areas of multiple explosions, especially missile fields. Prudent Americans, even those living several hundred miles from important targets, whenever practical should equip their shelters with adequate ventilating pumps and dust filters.

This potential danger from extremely small fallout particles will be worsened if the United States deploys mobile ICBMs such as Midgetman, probably on large military reservations in the West. (The Soviet Union already has mobile ICBMs in its nuclear forces.) In the event of a Soviet attack, our hard-to-target mobile missiles probably would be subjected to a barrage of relatively small warheads air-bursted so as to blanket their deployment areas. The resultant large clouds of extremely small radioactive particles in the troposphere usually would be blown eastward, and resultant life-endangering "hot spots" from rain-outs and/or snow-outs could be scattered clear to the Atlantic coast.

Fortunately, even in many expedient shelters completed in a few days, filtered air can be provided by using a homemade KAP to pump air through furnace or air-conditioner filters, as described in the last section of Appendix B. To learn how you can supply a shelter at low cost with air so well filtered that essentially all extremely small fallout particles and infective aerosols are removed, see Appendix E, How To Make a Homemade Plywood Double-Action Piston Pump and Filter.

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These worsening potential dangers from extremely small "hot" fallout particles brought promptly to earth by scavenging are not likely to endanger nearly as many Americans' lives as would 24-hour fallout of much larger particles from surface and near-surface explosions. Providing enough outdoor air to shelters, rather than filtered air, will continue to deserve first priority.

STOPPING OR RESTRICTING SHELTER VENTILATION

When instrument readings or observations show that heavy fallout has begun to be deposited, shelter occupants should decide whether to restrict or stop ventilation. If it is windy outside, even some sand-like fallout particles may be blown into a shelter with large ventilation openings. However, ventilation should not be restricted long enough to cause weaker occupants to be on the verge of collapse from overheating, or to result in headaches from exhaled carbon dioxide.

If a house is burning dangerously close to a separate, earth-covered shelter, closing the shelter's ventilation openings for an hour or two usually will prevent the entry of dangerous concentrations of carbon monoxide, carbon dioxide, or smoke. (Most houses will burn to the ground in less than two hours.)

When an attack is expected, a shelter, occupied or soon to be occupied, should be kept as cool as practical by pumping large volumes of outdoor air through it when the outdoor air is cooler than the shelter air. This also will assure that the air is fresh and low in exhaled carbon dioxide. Then, if a need arises to stop or restrict ventilation, the shelter can be closed for longer than could be done safely otherwise.

VENTILATION/COOLING OF PERMANENT SHELTERS

A permanent family fallout shelter, built at moderate cost before a crisis, should have a ventilation system that can supply adequate volumes of either filtered or unfiltered air, pumped in through an air-intake pipe and out through an air-exhaust pipe. Provision also should be made for the grim possibility that fallout could be so heavy that a shelter might have to be occupied for weeks, or even part-time for months. A small or medium-sized permanent shelter should be designed so that most of the time after an attack it can have adequate natural ventilation through its entryway and emergency exit. During hot spells, forced ventilation through these same large air passageways should be provided by using a homemade KAP. This manual air pump, described in Appendix B, can force large volumes of air through low-resistance openings with minimum effort.

Ways to ventilate and cool permanent shelters are described in Chapter 17, "Permanent Family Fallout Shelters for Dual Use," and in Appendix E, "How to Make and Use a Homemade Plywood Double-Action Piston Pump and Filter."

WARNING: MANY OFFICIAL INSTRUCTIONS FOR BUILDING AND VENTILATING SHELTERS ARE LIFE-ENDANGERING

The reader is advised not to read this section if pressed for time during a crisis, unless he is considering building an expedient or permanent shelter described in an official civil defense publication.

Because of the worldwide extreme fear of radiation, civil defense specialists who prepare official self-help instructions for building shelters have made radiation protection their overriding objective. Apparently the men in Moscow and Washington who decide what shelter-building and shelter-ventilating instructions their fellow citizens receive — especially instructions for building and improving expedient shelters—do not understand the ventilation requirements for maintaining endurable temperature/humidity conditions in crowded shelters. It must be remembered that shelters may have to be occupied continuously for days in warm or hot weather.

Russian small expedient shelters are even more dangerously under-ventilated than are most of their American counterparts, and can serve to illustrate similar ventilation deficiencies of American shelters. Figure 6.5 is a Russian drawing (with its caption translated) of a "Wood-Earth Shelter" in a Soviet self-help civil defense booklet, "Anti-Radiation Shelters in Rural Areas." This booklet, published in a 200,000-copy edition, includes illustrated instructions for building 20 different types of expedient shelters. All 20 of these shelters have dangerously inadequate natural ventilation, and none of them have air pumps. Note that this high-protection-factor, covered-trench shelter depends on air flowing down through its "Dust Filter with Straw Packing (hay)" and out through its small "Exhaust Duct with Damper."

As part of Oak Ridge National Laboratory's participation in Defense Nuclear Agency's "Dice Throw" 1978 blast test, I built two Russian Pole-Covered Trench Shelters. These were like the shelter shown in Fig. 6.5, except that each lacked a trapdoor and filter. As anticipated, so little air flowed through these essentially dead-ended test shelters that temperatures soon became unbearable.

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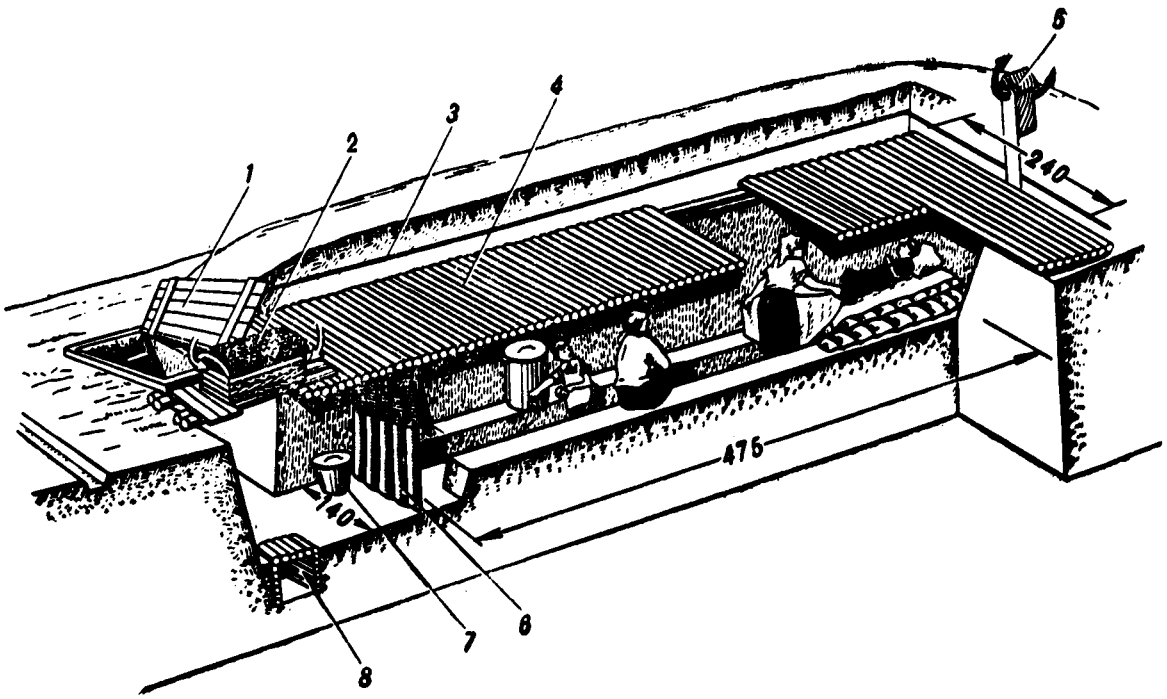


Fig. 6.5. Figure 20. Wood-Earth Shelter without Lining of the Walls for Clay Soils, 10 Occupants: 1 - Trap Door; 2 - Dust Filter with a Straw Packing (hay); 3 - Earth Cover 60-80 cm thick; 4 - Roofing made of Poles; 5 -Exhaust Duct with Damper; 6 - Curtain made of Tightly Woven Cloth; 7 - Removable Container for Wastes; 8 - Water Collecting Sump.

NOTE: Bill of materials is: Rough Lumber, 2.7 cubic meters; Nails, 0.12 kilogram; Wire, 0.64 kilogram; Work Requirement, 90-110 man-hours; Shielding Coefficient, 250-300.

Russian earth-covered expedient fallout shelters are based on military dugouts designed for brief occupancy during a conventional attack. Subsequently, they were improved for fallout protection but were made much less habitable by Soviet civil defense specialists. Apparently these specialists were ignorant of ventilation requirements, and almost certainly they did not field-test small expedient fallout shelters for habitability. Tens of millions of Russians have been taught to build such shelters.

Once any bureaucracy issues dangerously faulty equipment or instructions, it rarely corrects them except under pressure. I have experienced this reluctance even during wartime, when trying to improve faulty combat equipment that was causing American soldiers to lose their lives. Continuing proofs of such bureaucratic reluctance to correct dangerous errors are hundreds of thousands of potentially life-endangering civil defense pamphlets and booklets — especially the several editions of *In Time of Emergency* — kept nationwide in hundreds of communities, primarily for crisis distribution.

Some American official instructions for building expedient shelters have been slowly improved over the decades; the best are given in the June 1985 edition of *Protection in the Nuclear Age,* one of the Federal Emergency Management Agency's widely available free booklets. Yet even in this improved edition no mention is made of the crucial need for forced ventilation during warm weather, nor for expedient, simple means for providing pumped air. Also, in the June 1985 edition of *Protection in the Nuclear Age,* the second crawlway entry/exit of the Above-Ground, Door-Covered Shelter (see Appendix A.4) is replaced by a "4-6" DIA. PIPE FOR VENTILATION," which makes this very small shelter essentially dead-ended and thereby eliminates adequate ventilation in warm weather. With only a 6-inch-diameter air-exhaust opening, not nearly enough air can flow naturally in warm weather through this crowded shelter's room (only about 39 inches wide by 34 inches high). As proved by habitability tests in Florida and elsewhere, a KAP or Directional Fan must be used, even with two crawlway entry/exits.

The essential second crawlway entry/exit of the Aboveground Door-Covered Shelter was eliminated as the result of a recommendation by a contractor for FEMA charged with field testing and evaluating expedient shelters, and improving abbreviated shelter-building instructions. No habitability tests were required. So the contractor concluded in his 1978 report to FEMA that the second entry/exit should be eliminated because "The building of entries is time consuming and with this small a shelter a second entry is really not justified."

In peacetime, bureaucracies of all nations tend to divide up responsibilities between specialists and to promote means by which nonprestigious wartime problems can apparently be solved with the least expense and work.

DIRECTIONAL FANNING TO VENTILATE SHELTERS

The Directional Fanning instructions on the following two pages may save more lives than any other instructions given in this book for a homemakeable survival item. I regret that no one rediscovered this premechanization, simple, yet effective way of manually pumping air until after the original *Nuclear War Survival Skills* was published.

In 1980, Dr. William Olsen, a NASA research engineer long concerned with improving self-help civil defense, rediscovered one kind of Directional Fanning. Since then, with the assistance of able Americans and others, I have designed and tested several types of Directional Fans. I have field-tested and repeatedly improved the instructions to enable average people to quickly learn how to make and use such fans effectively.

The great advantage of Directional Fanning is that almost anyone who is given the field-tested instructions can quickly make and use one of these simple fans. Only very widely available materials are needed. The main disadvantage is that Directional Fanning is a more laborious way to ventilate a shelter than using KAPs, as described in detail in Appendix B.

Americans are not likely to receive Directional Fanning instructions from the Federal Emergency Management Agency. FEMA's predecessors, the Office of Civil Defense and the Defense Civil Preparedness Agency, were unable to get the millions of dollars necessary to buy factory-made KAPs and other manual air pumps to ventilate officially designated fallout shelters, and FEMA has avoided shelter ventilating controversies. No widely available official American publication includes instructions for making and using any expedient air-pumping device.

Thanks to Congressman Ike Skelton, Democrat of Missouri and strong civil defense advocate, in 1981 I was able to demonstrate Directional Fanning to Louis Giuffrida, at that time the Director of FEMA. I gave Directional Fans to the FEMA specialists concerned with shelter ventilation, all of whom have since left FEMA. To date, although Directional Fanning instructions have been reproduced in three private civil defense publications, and some 600 copies of a metric version of the instructions were distributed to British civil defense professionals at the 1984 Annual Study of Civil Defence and Emergency Planning Officers, FEMA has not even evaluated Directional Fanning.

In contrast, in 1981 I gave copies of instructions for both KAPs and Directional Fans to Dr. Yin Zhi-shu, the Director of the People's Republic of China's National Research and Design Institute of Civil Defense — and the next day he started evaluating these simple devices. (At that time I was traveling extensively in China as an official guest, exchanging civil defense information.) Dr. Yin, who heads all Chinese civil defense research and development, went with his top ventilation and shelter design specialists to a furniture factory in Beijing. There I watched workmen quickly build both a large and a small KAP, and also Directional Fans. Then Dr. Yin and his specialists began using their air-velocity meters to measure the volumes of air that these simple devices could pump. On the following days I participated in more ventilation tests using KAPs and Directional Fans in tunnel blast shelters in Beijing and in the port city of Dalien.

While watching these top Chinese civil defense professionals make and test KAPs and Directional Fans, I kept thinking: "This is the way Thomas Edison and Henry Ford would have evaluated simple devices of possible great importance to millions."

The reader is urged to keep the following two pages of Directional Fanning instructions ready for reproduction in a crisis. The sections on the small 2-handled Directional Fan and the large 1-Man Fan will be the most useful to unprepared people. Ventilation by pairs of men using Bedsheet Fans is an effective method for forcing very large volumes of outdoor air through tunnels, corridors and mines with ceilings at least 9 feet high — provided they have two large openings. However, this method requires organization and discipline.

DIRECTIONAL FANNING TO VENTILATE SHELTERS

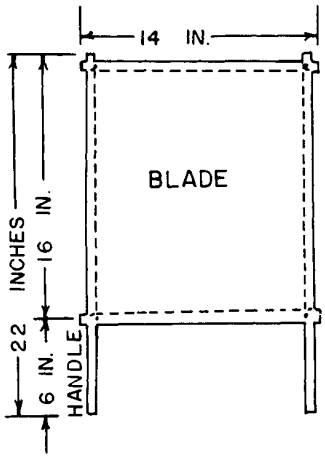
Directional Fanning is the simplest way to force enough outdoor air through typical basement, trench, and other expedient shelters to maintain endurable conditions, even in extremely hot, humid weather.

During a worsening nuclear crisis most unprepared citizens probably will not have the time and/or materials needed to make a KAP or other efficient shelter-ventilating pump — even if they have the instructions. In contrast, tests with average citizens have indicated that if they have instructions for making and using Directional Fans and if there are a few hours of warning time before the attack, then the majority will be able to ventilate all of their expedient shelters, except some of the largest.

The principal disadvantage of Directional Fans is that they are more laborious to operate than are KAPs, that are manually powered, pendulum-like air pumps that conserve energy.

A. DIRECTIONAL FANNING TO VENTILATE AND COOL SMALLER SHELTERS

A **2-Handled** Directional Fan of the size illustrated is less tiring to use and requires less manual dexterity than does a 1-handled fan with the same size blade. With this small 2-handled fan you quite easily can force about 300 cubic feet per minute (300 cfm) of outdoor air through a crowded trench or basement shelter. This is enough air for up to 9 adults crowded into a small shelter in extremely hot, humid weather, and enough for about 100 people in cold weather. By fanning vigorously, 500 to 600 cubic feet per minute have been forced through a small covered-trench shelter.



To make a durable 2-handled fan, first make its frame out of 2 sticks each 14 inches long and 2 sticks each 22 inches long. See sketch. To strengthen the corners, overlap the sticks about one-half inch, as shown.

When using sticks cut from a tree, select ones with diameters of about ¾ inch, and make shallow notches in all 4 sticks before tying together the 4 corners of the blade. If you do not have strong string, use ¾-inch-wide strips of bedsheet cloth, or other strong cloth, slightly twisted.

If using sawed sticks, be sure to use none smaller than ⅜ x ¾ inch in cross section. If you have very small nails or brads, use only one to connect each corner; then tie each corner securely. To prevent possible blistering of hands, wrap cloth around the fan handles, or wear gloves.

To cover the fan's blade, any strong, light fabric, such as bedsheet cloth, serves well. If you are going to sew on the cloth, first cut a 26 x 30-inch piece. Wrap the 30-inch width smoothly crosswise around the frame, after cutting 4 notches in the cloth's corners, so that the tied-together parts of the sticks will not be covered. Pin or tape the cloth to make a smooth blade; finally sew securely. (If waterproof construction adhesive is available, a smaller piece of cloth can be used and the blade can be covered in a very few minutes.)

If time and/or materials are very limited, **make a fan with its blade merely a piece of cloth connecting two 22-inch-long sticks.** This very simple fan is reasonably effective, although tiring to use.

Cardboard covering a blade is likely to become damp and fragile in the humid air of a crowded shelter. Very light sheetmetal makes a good fan blade and requires only 2 sticks. A blade of ¼-inch plywood is too heavy.

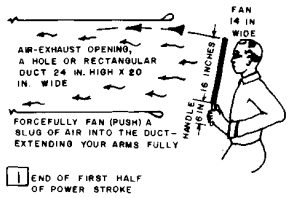
If no sticks are available, a double thickness of heavy, stiff cardboard 22 inches long by 14 inches wide will pump almost as much air if used as a handleless fan. The pieces should be securely tied or taped together. If waterproof tape is available, cover the parts that you will grip with sweaty hands, thus preventing dampening and softening the cardboard.

For maximum ventilation, the air-intake opening of a shelter should be at least as large as its air-exhaust opening. (If the air-exhaust opening of your small shelter is much larger than that shown in the sketches, block part of it off to reduce it to approximately this 24-inch-high by 20-inch-wide size, for more effective use with this fan.) The air should be fanned out of the shelter in the direction in which the air is naturally flowing. For maximum ventilation rate, fan about 40 strokes per minute.

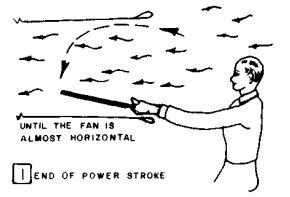
With one or more Directional Fans, air inside a shelter can be distributed effectively and the occupants cooled. Also, if during the time of maximum fallout dose rate the occupants get close together in the most protective part of the shelter, they often will get unbearably hot unless fanned.

To fan air out through an air-exhaust opening, sit facing the opening with your elbows about 4 inches lower than the bottom of the opening. Then count 1, 2, 3 while you:

1 **Quickly** raise the fan to a vertical position close in front of your face and **immediately** fan (push) a slug of air into the opening — ending the power stroke with your arms fully extended and with the fan almost horizontal and out of the way of air that was "sucked" behind the fan and is still flowing out through the opening.

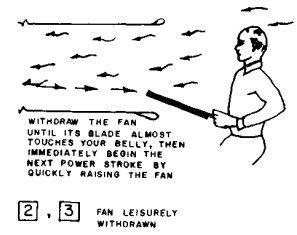


2, 3 After a slight pause, leisurely withdraw the almost horizontal fan until the bottom of its blade almost touches your stomach — preparatory to the next power stroke.



To increase the flow of air through a shelter, while fanning the occupants:

Have two or more occupants sitting inside the shelter each use a fan of the size described above to fan the air so as to increase its velocity in the direction in which air already is flowing through the shelter. Such Directional Fanning is especially effective in increasing the air flow through small, narrow shelters.

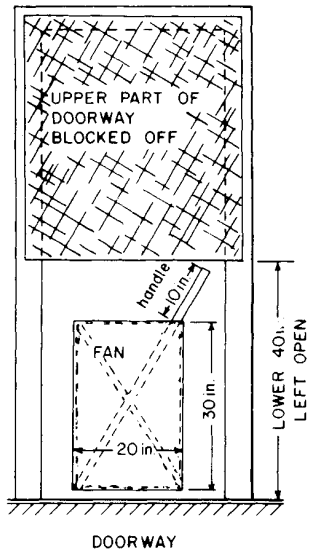


To avoid higher radiation exposures near openings, build an essentially airtight partition across the shelter room, with a 24-inch-high x 20-inch-wide hole in it through which to fan. By fanning through a 24 x 20-inch hole in a cardboard partition built across a doorway inside a U-shaped permanent trench shelter 76 feet long, the air flow was increased by an average of 327 cubic feet per minute.

B. DIRECTIONAL FANNING TO VENTILATE AND COOL LARGER SHELTERS

1. With a Large 1-Man Fan

To ventilate larger basements, big covered trenches, and other large shelters lacking adequate ventilation, use one or more large 1-man fans. See sketch. Note that the 20 x 30-inch fan blade is made like a 2-stick kite, and that the upper end of the longer diagonal stick serves as a 10-inch handle. The model illustrated is made of 2 nominal 1 x 2-inch boards, one 46 inches long and the other 35 inches long. These boards are connected at a point 17½ inches from their lower ends, first with a single clinched nail, and then by being tied securely. The edges of the handle are rounded smooth.



The blade frame is covered on both sides with strong bedsheet cloth, that is wrapped around and secured to the strong cords or wires tied to notches cut in the boards (or sticks) near the 4 corners of the blade. (If cord or wire is not available, 4 2-inch-wide strips of strong cloth, slightly twisted, serve well.)

A durable but laboriously heavy fan can be made in a few minutes using a 20 x 30-inch piece of ¼-inch plywood nailed to a single 46-inch-long, 1 x 2-inch board. Or use a single round stick about 1¼ inches in diameter, flattened on one side.

A fan with its blade made of two sheets of very heavy cardboard tied on both sides of a 1 x 2-inch board is decidedly effective when dry. However, typical cardboard will become soft and worthless in most crowded, long-occupied, humid shelters.

To fan directionally, it is best to stand just outside and to one side of a doorway, so that your body does not obstruct the air flow. Preferably stand opposite and facing the open door, which should be secured open and perpendicular to its doorway. Hold the fan like a golf club and swing it with your arms extended. Then slowly count 1, 2 while you:

[1] Make the power stroke with the fan blade broadside until the end of the stroke, when you quickly turn it 90 degrees.

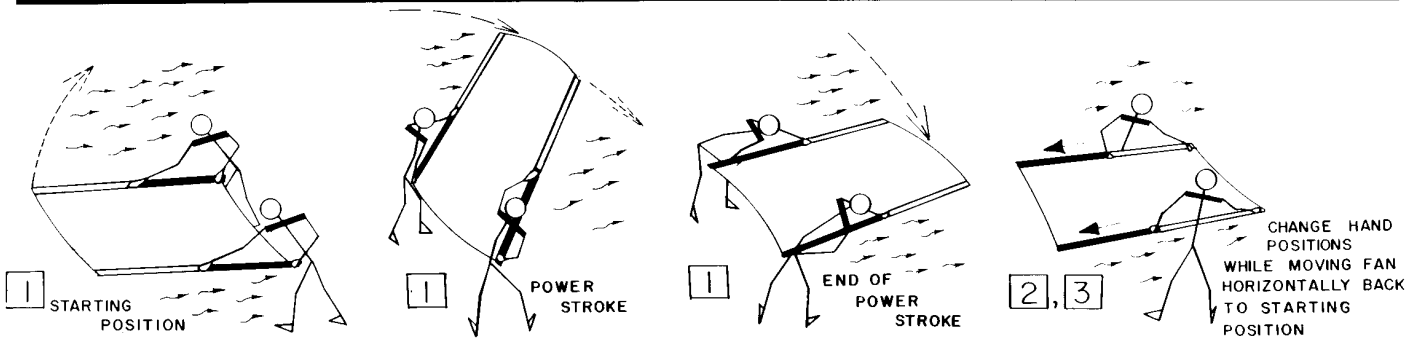
[2] Make the pendulum-like return stroke with the fan blade kept edgewise ("feathered") to the air flow until the end, when you quickly turn it 90 degrees, preparatory to making the next power stroke.

To pump more air, block off the upper part of the doorway with cloth, cardboard, plywood, etc., to prevent air from flowing back in the wrong direction through the upper part of the doorway. See sketch on preceding page.

Whenever practical, directionally fan the air in the same direction that the air is naturally flowing through the shelter. More air usually can be pumped through a shelter if the fan is used to force air out through the air-exhaust opening. This reduces the air pressure inside the shelter and causes fresh outdoor air to be "sucked" into the shelter through the air-intake doorway, or through other large air-intake openings. Thus with one fan 1,000 cubic feet per minute can be pumped through a fully occupied shelter. This is enough outdoor air — if it is properly distributed within the shelter — to maintain tolerable conditions for weeks for 25 occupants during extremely hot weather, and for up to about 300 occupants during cold weather.

To ventilate and cool a room having only one doorway and no other opening, do not block off any part of the doorway. If air is fanned into such a room through the lower part of its completely open doorway, then air will flow back out of the room through the upper part of the doorway. However, this pumps much less air than when a separate, large air-exhaust opening is provided.

To increase the flow of outdoor air through a tunnel-shelter, several fanners equally spaced along its length should each fan in the direction of the natural air flow. This procedure was first proved practical during a 1981 ventilation test that Cresson H. Kearny participated in with Chinese civil defense officials in the port city of Dalien. In this test 5 fanners, each with a fan of approximately the size illustrated, forced air from the outdoors through a 395-foot section between two opened entrances of a typical Chinese tunnel-shelter. The air flow was increased from a natural flow of 290 cubic feet per minute to 3,680 cubic feet per minute. The 5 excellent Chinese fans each had a blade made of a piece of 3 mm (approx. ⅛ inch) plywood nailed to a single board.



2. With a Bedsheet Fan

Use a 2-man Bedsheet Fan to force thousands of cubic feet per minute of outdoor air through a tunnel or long corridor having at least a 9-foot ceiling and a large opening at each end. The most practical design tested was made from a strong double bedsheet cut down to 6-foot width, with the wide hem at its head-end left unchanged and with a similar-sized hem sewn in its opposite end, to give a finished length of 6 feet. A 6-foot-long, nominal 1 x 2-inch board (or an approximately 1½ inch diameter stick) was secured inside each end hem of various models with waterproof construction adhesive, or with tacks, or by tying. Before a board was inserted, its edges were rounded. Round sticks were smoothed.

Two persons preparing to use a Bedsheet Fan (see sketch) should stand facing each other, at right angles to the desired direction of air flow, with the cloth extended horizontally between them. Each fanner should grip his stick with one hand near its "downwind" end and with his other hand near its center.

A pair of Directional Fanners get ready to make a power stroke by leaning in the upwind direction, as illustrated. Then the pair of fanners should count 1, 2, 3 while they:

[1] Make the power stroke by rapidly sweeping their sticks and the attached cloth in an arc, until they are leaning in the downwind direction and the sticks and cloth are again horizontal. See sketch.

[2], [3] Hold the sticks and cloth horizontal (to permit air that was "sucked" behind the cloth to continue flowing in the desired direction) while leisurely moving the Bedsheet Fan back to the starting position. During this move the fanners change hands, as illustrated. (Note that what was the upper side of the fan at the beginning of the power stroke now has become the lower side.)

Two men thus fanning vigorously produced a net air flow of 5,500 cubic feet per minute through an empty school corridor that is 8 feet wide, has a 9-foot ceiling, and is 194 feet long. The doors at both ends were open. To adequately ventilate and cool people crowded into a long tunnel in hot weather, a pair of Bedsheet Fanners should be positioned about every 100 feet along its length.

The practicality of using Bedsheet Fans to ventilate some very large mines or caves having 2 or more large openings was proved by tests with members of the Citizens Preparedness Group of Greater Kansas City. These tests were conducted in 1982 near Kansas City in a huge limestone mine that has a ceiling averaging about 17 feet high, corridors about 35 feet wide, columns of unexcavated rock about 15 feet square, and over 1,000,000 square feet of level, dry floor space. The air inside is "dead", remarkably still, because the only openings are two truck-sized portals on one side of the mine. Five pairs of Bedsheet Fanners, spaced about 75 feet apart down a corridor, after fanning for several minutes produced a measured air flow of approximately 100,000 cubic feet per minute through this part of this corridor!

With many more pairs of Bedsheet Fanners working, enough air for at least 10,000 occupants could be "sucked" into this mine through one of its 17 x 20-foot portals, fanned down a corridor to the far "dead end" of the mine, then fanned through a cross corridor, and finally fanned back out through the corridor that has the second truck-sized portal at its outer end.

A pair of pre-mechanization coal miners produced a directed airflow by holding a piece of canvas **vertically** between them while they quickly walked a short ways in the direction of the desired airflow; they walked back with the canvas held **horizontally** between them. Then they repeated.

C. ADDITIONAL ADVANTAGES OF DIRECTIONAL FANS

1. No installation is needed, thus saving working time and materials for making habitable shelters hurriedly built or upgraded during a crisis.

2. Directional Fans enable shelter occupants to quickly reverse the direction of air flow through their shelter when outdoor wind changes cause the direction of natural air flow to be reversed.

3. Four or more Directional Fans when used to circulate air within a shelter room can serve like air ducts, while simultaneously fanning occupants.

4. Directional Fans are very unlikely to be damaged by blast effects severe enough to wreck bladed fans or other fixed ventilation devices placed at or near air-intake or air-exhaust openings, but not severe enough to injure shelter occupants.

Chapter 17
Permanent Family Fallout Shelters for Dual Use

THE NEED

Having a permanent, ready-to-use, well supplied fallout shelter would greatly improve millions of American families' chances of surviving a nuclear attack. Dual use family shelters — shelters that also are useful in peacetime — are the ones that Americans are most likely to build in normal peacetime and to maintain for years in good condition for use in a nuclear war.

The longer nuclear peace lasts, the more difficult it will be, even during a recognized crisis, to believe that the unthinkable war is about to strike us and that we should build expedient shelters and immediately take other protective actions. The lifesaving potential of permanent, ready-to-use family shelters will increase with the years.

Americans who decide to build permanent shelters need better instructions than can be obtained from official sources or from most contractors. This chapter brings together fallout shelter requirements, based on shelters and shelter components that have been built and tested in several states and nations. The emphasis is on permanent fallout shelters that many Americans can build for themselves. The author believes that millions of Americans can build good permanent fallout shelters or have local contractors build them — if they learn the shelter requirements outlined in the following sections of this chapter and the facts about nuclear weapon effects and protective measures given in preceding chapters. Builders can use their skills and available local resources to construct permanent, dependable fallout shelters at affordable cost.

Requirements for a permanent, dual-use family fallout shelter follow.

A HIGH PROTECTION FACTOR, AT AFFORDABLE COST

A permanent fallout shelter should be built — and can easily be built — to have a high enough protection factor to prevent its occupants from receiving fatal or incapacitating radiation doses, and also from receiving doses large enough to seriously worsen their risks of developing cancer in the years following an attack. Shelters with a protection factor of 40 (PF 40) meet the minimum standard of protection for public shelters throughout the United States, and permanent family fallout shelters described in official pamphlets provide at least PF 40 protection. In almost all fallout areas, PF-40 shelters would prevent occupants from receiving fatal or incapacitating radiation doses while inside these shelters. However, in areas of heavy fallout the occupants of PF-40 shelters could receive radiation doses large enough to significantly contribute to the risk of contracting cancer years later. Furthermore, the larger the dose you receive while in a shelter, the smaller the dose you can receive after you leave shelter without being incapacitated or killed by your total dose.

If you build a permanent shelter, you would be foolish to build a shelter with a PF of only 40 when additional protection is so easy to obtain. By making a shelter with a 6-inch-thick concrete roof covered by 30 inches of shielding earth, and with other easily attained design features shown in Figs. 17.1 and 17.2, you can have a shelter with a protection factor of about 1000. (An occupant of a PF 1000 shelter will receive a radiation dose only 1/1000th as large as he would receive if he were standing outside in an open field during the same time interval.) To attain PF 1000 protection near the inner door of the illustrated

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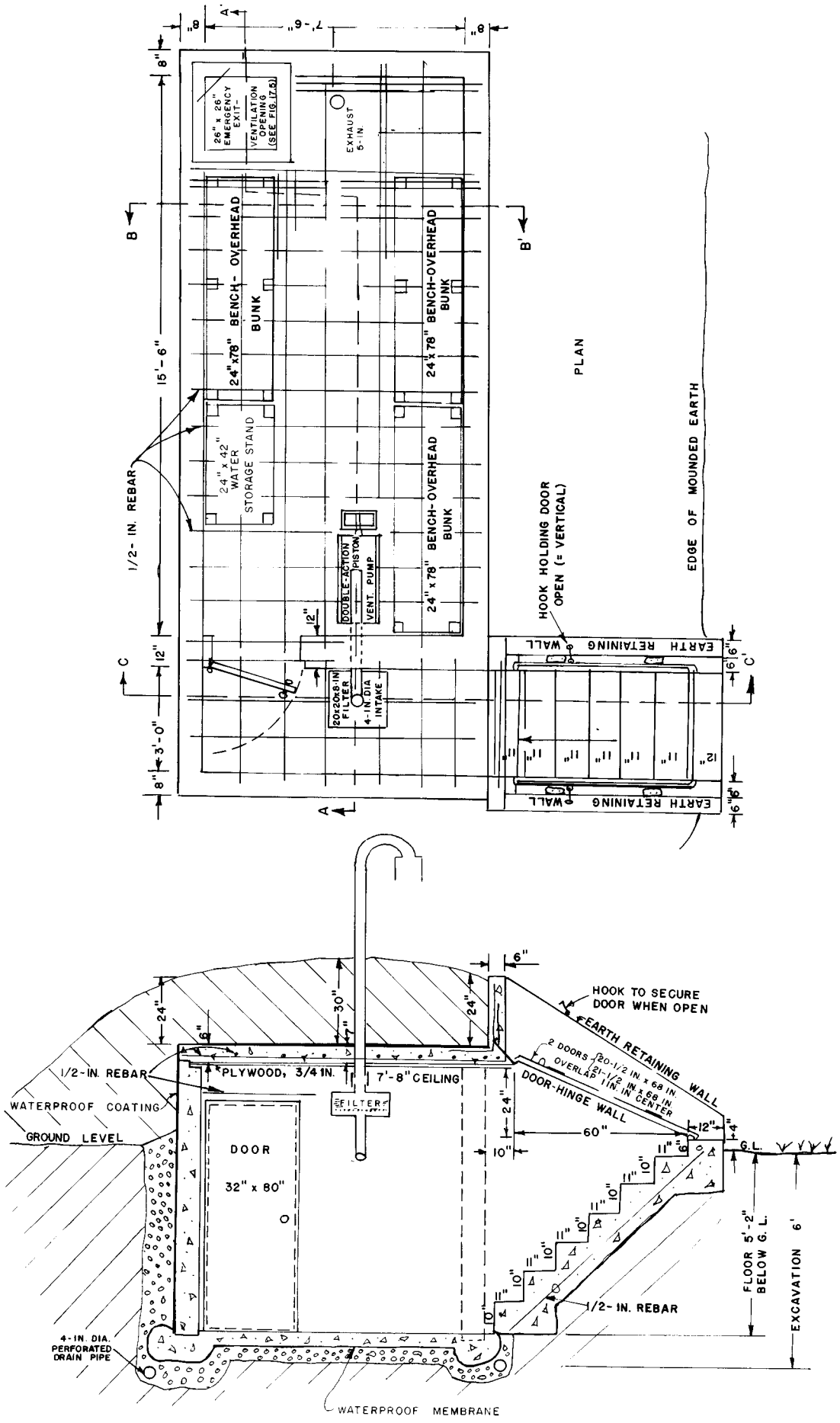
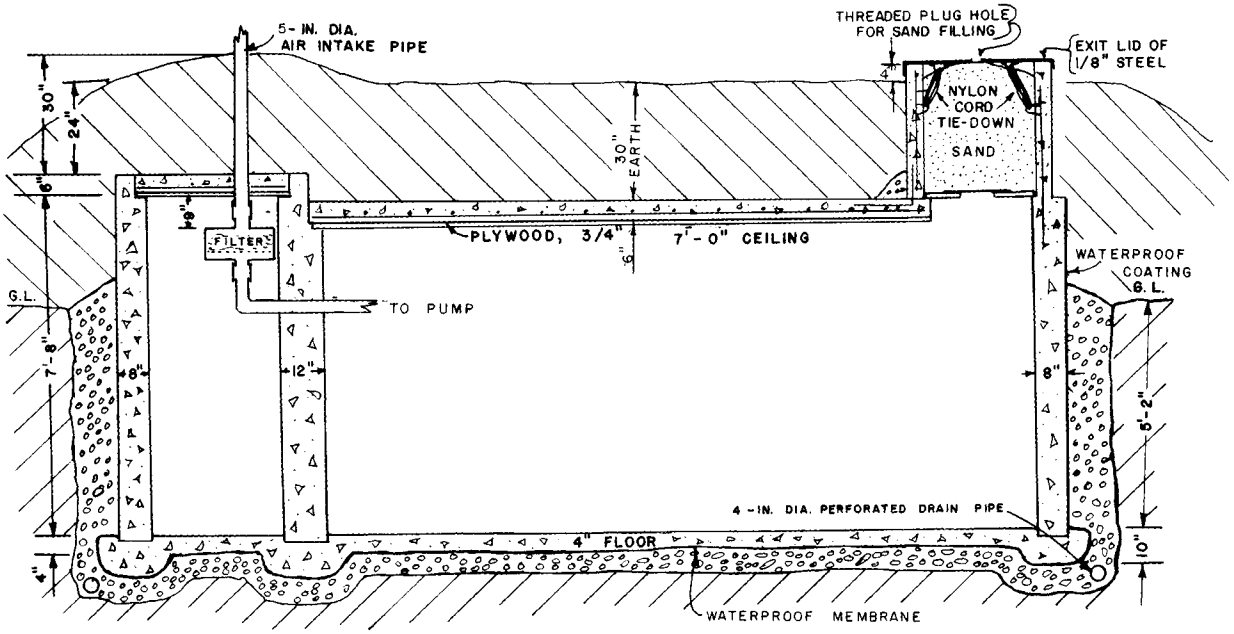
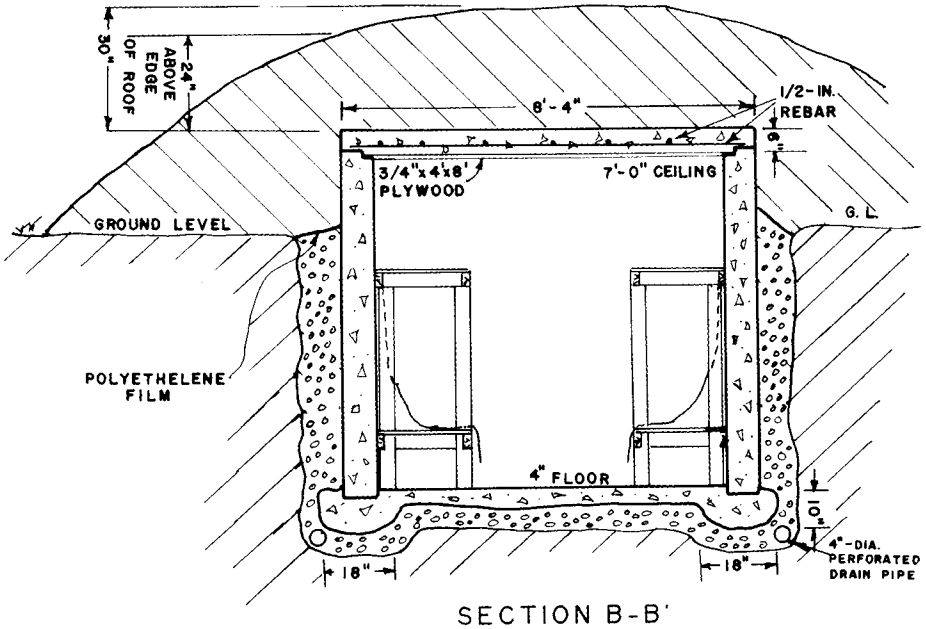


Fig. 17.1. Permanent Family Fallout Shelter for Dual Use.

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SECTION A-A'



SECTION B-B'

Fig. 17.2. Permanent Family Fallout Shelter for Dual Use.

shelter, its occupants must place containers full of water and/or other good shielding material against the door. They can do this easily and quickly if the shelter is supplied with filled water containers such as described in the Water section of this chapter.

The illustrated shelter room has 106 square feet of floor space — room enough for 5 adults and the survival essentials they will need for long occupancy, if shelter furnishings like those described in this chapter are provided. For each additional occupant, increase this shelter's length by 2 feet. To increase room size, increase length and not width. This retains maximum roof strength at minimum cost.

Note in Figs. 17.1 and 17.2 the 12-inch-thick concrete wall between the landing at the foot of the stairs and the end of the shelter room. Only a very small fraction of the radiation coming through the outer doors and down the stairs will make the 90 degree turn through the inner door, and most of this radiation will not strike shelter occupants if they place containers filled with water and other shielding material against the door.

Also note the homemakeable, low cost Double-Action Piston Pump and filter, shown in Fig. 17.1, that even in a heat wave will supply adequate air through the 5-inch-diameter air-intake pipe — all described in Appendix E.

Few survival-minded Americans, before a recognized international crisis arises, either can afford or believe that they can afford to build a permanent family fallout shelter costing around $10,000 in 1987. A small reinforced concrete, below-ground shelter of the type specified in official Federal Emergency Management Agency pamphlets costs about $100 per square foot of floor space, if built by a contractor in a typical suburban area. Those with the needed skills and time can save about half of this cost by doing their own work. Also, at many building sites where gravity drainage of the earth around a shelter's walls can be assured and hydrostatic earth pressure against the walls thus prevented, no steel reinforcement in the poured concrete or concrete block walls is needed — unless required by the local building code.

Caution: Steel reinforcement in the walls and floor is needed in some clay soils that swell when wet and exert sufficient inward and upward pressure to crack unreinforced walls and floor slabs. Consult local builders who have learned from experience whether wall and floor reinforcement is needed in the type of soil where you plan to build. If needed, a grid of ½-inch rebars, spaced at 12 inches, usually is adequate. To save money on steel reinforcement, check prices in salvage yards for used rebars and substitute reinforcing materials such as junked cable and small pipes.

How to safely pour a shelter's concrete roof slab without using a contractor's usual forms and equipment is indicated by Figs. 17.1 and 17.2. These drawings show 8-ft.-long sheets of ¾-inch plywood supported at their ends on shelter walls 7 feet-6 inches apart. Preparatory to pouring the concrete, the plywood sheets should be supported along the centerline of the shelter by 4"x4"s and other lumber, which can be used later to build seats and overhead bunks. Plywood left on the ceiling reduces condensation and heating problems in cold weather, but increases the volume of outdoor air that must be pumped through the shelter to maintain tolerable temperatures when it is occupied in hot weather. This was clearly demonstrated in the summer of 1963 when the author used SIMOCS (simulated occupants that produce heat and water vapor like people) to determine the habitability of a six-roomlet below ground group shelter, with a reinforced concrete roof that had been built in this manner by six New Jersey farm families. They had left ordinary ¾-inch exterior plywood on the ceiling. Because the hollow concrete wall-blocks and the well drained gravel under the floor also kept heat from escaping into the surrounding soil, and because only natural ventilation was provided, the temperature/humidity became dangerously high within a few hours.

Insulating a shelter's walls and ceiling can be disadvantageous, because insulation makes unavailable the "heat sink" of the shelter and its surrounding earth. In hot weather insulation reduces the time during which ventilation can be stopped or restricted without disastrously overheating the occupants.

Today, for such a shelter it would be better to use pressure-treated, rot-proof plywood and lumber, approved by leading building codes. For information, write to the American Plywood Association, P.O. Box 11700, Tacoma, WA 98411, enquiring about rot-proof plywood, dimensional lumber, and other material used in building the All-Weather Wood Foundation. Most lumber yards will obtain treated plywood on order, and sell it for about 50% more than ordinary exterior grade plywood.

Big savings in shelter construction costs are made by using salvaged and/or used materials. Manufacturers of pre-cast reinforced concrete beams and floor sections often sell rejects for very little. Most salvage yards have steel beams

and other material that make excellent roofing for earth-covered shelters. (Shortly before the Cuban Missile Crisis, when living near New York, I built for myself at modest cost a very small shelter on a well drained hillside. I made it almost entirely of steel channels bought and cut to order at a salvage yard.) Used cylindrical steel tanks with closed ends often make good low-cost permanent shelters. One of the best low-cost family shelters that I ever went into was on a hillside overlooking San Francisco Bay. It was made of a salvaged steel brewing tank that had been installed after a vertical cylindrical entrance with a door had been welded on it. The tank's exterior had been protected with a bituminous coating. Its survival-minded owner was a brilliant Hungarian refugee who, as a boy, had survived in a deep wine cellar throughout the Russian siege and shelling of Budapest. Nothing equals war experience to teach the lifesaving value of shelters.

MINIMIZATION OF FIRE AND CARBON MONOXIDE DANGERS

Many shelter designers and builders do not realize the probable extent of fires after a major nuclear attack. Nor do the big majority of them provide shelters built under or close to a house with adequate protection against the entry of deadly amounts of carbon monoxide if the house burns. Although the areas of fires resulting from a nuclear explosion generally will be about as extensive as the areas of significant blast damage,[6] on a clear day a house up to about 8 miles from ground zero can be ignited by the thermal pulse of a 1-megaton airburst.[6] Figure 7.2 in Chapter 7 is a photograph of a car set on fire by a nuclear explosion so far away that the car was not even dented by the blast. This photograph indicates how a thermal pulse can go through window glass and ignite curtains, upholstery, or dry paper, even if flammable material outdoors is too damp to be ignited. Furthermore, fires from any cause can spread, especially in fallout areas following a nuclear attack when firefighters may be unable or unwilling to expose themselves outdoors to radiation.

Good protection against carbon monoxide is provided by a permanent earth-covered shelter, built with its entry outdoors and well separated from a house and other flammable structures, and constructed so that it can be closed gas-tight. Both the air-intake and the air-exhaust pipes should be installed so that they can be quickly closed air-tight, as with screw-on fittings. Such closures should be kept well greased and securely attached close to where they would be used. If a shelter's entry is through a passageway from a house, a gasketted steel firedoor, insulated on the shelter side, should be installed near the house end of the passageway. The shelter should be further protected by a second gas-tight door, to prevent the entry of carbon monoxide and smoke if heat from the burning house destroys the gasket on the firedoor. If special firedoor gaskets are not available, rubber weatherstripping will serve. To lessen the risk of carbon monoxide being pumped into the shelter if the house burns and air must be pumped into the shelter while the fire still is smoldering, the air-intake and pump should be at the far end of the shelter, and the air-exhaust pipe and emergency exit should be near the passageway from the house.

Be sure to seal electrical conduits leading from a basement to a connected shelter, so that if the house burns carbon monoxide can not flow through the conduits into the shelter when fresh outdoor air is not being pumped into the shelter. The author, while conducting ventilation and habitability tests of an earth-covered blast shelter connected through a tunnel to a house's basement, observed air flowing out through unsealed conduits, the reverse of such a possible life-endangering flow of carbon monoxide. When the shelter was being maintained at a slight overpressure by cranking its blower to pump in outdoor air, a little air flowed through the unsealed conduit into the basement.

For ways to minimize carbon monoxide dangers arising from cooking, heating, lighting, and smoking, see following sections in this chapter.

Remember that air contaminated with only 0.16% carbon monoxide can kill you in 2 to 3 hours, and 0.04% carbon monoxide causes frontal headaches and nausea in 2 to 3 hours. The Navy sets its safe allowable carbon monoxide concentration in air at 0.01%. (*Shelter Habitability Studies — The Effect of Oxygen Depletion and Fire Gasses on Occupants of Shelters,* by J. S. Muraoka, Report NCEL-TR-144, July 1961.)

PREVENTION OF CRACKS AND WET SHELTER PROBLEMS

If wet basements are a problem in your locality, below ground shelters are likely to be wet and unsatisfactory unless appropriate preventative measures are taken during their design and construction. When making plans, you should consult local builders of satisfactory basements. You also should question persons who at various times of the year have observed excavations, holes, and/or basements in your immediate vicinity, or have noted seasonal swampy places or springs.

The most difficult type of shelter to keep dry for decades is one that is wholly or partially below the water table for part or all of the year. Concrete is not completely watertight. Waterproof coatings and coverings often are damaged during construction, or deteriorate with age.

Shelter walls sometimes crack due to settling and earth movements. Metal shelters usually develop small leaks long before they become dangerously weakened.

A 100-occupant, below ground shelter, built in 1984 near Dallas, Texas as a prototype blast shelter for industrial workers, was flooded when the water table rose. The poorly sealed opening of this shelter's emergency exit was below ground level, and after heavy rains was below the water table. A prudently designed shelter has the top of its emergency exit slightly above the surface of the surrounding earth, as illustrated in Fig. 17.2. All underground electric conduits leading down into a shelter must be well sealed to prevent entry of water.

To prevent a wholly or partially below-water-table shelter from becoming wet inside sooner or later, it should have a sump and an automatic sump pump to discharge water to the ground outside. If at any time you find that the sump pump is discharging an appreciable amount of water, you may have a serious wet-shelter problem if electric power fails after an attack.

A manually operated bilge pump and a sufficiently long discharge hose can be bought for about $20.00 from marine supply mail order firms, including West Marine Products, Box 5189, Santa Cruz, California 95063, and Defender Industries, Inc., P.O. Box 820, New Rochelle, New York 10802-0820. (Long established marine supply companies also are good sources of use-proven chemical toilets, first aid kits, lights, rope, etc.)

Shelter roof surfaces should be gently sloped, no matter how good a waterproof coating is to be applied. By making a concrete shelter roof as little as 1 inch thicker along its centerline than along its sides, so that it slopes to both sides, the prospects are improved for having an earth-covered coated roof that will not leak for decades.

Figures 17.1 and 17.2 illustrate the following ways to prevent having a wet shelter:

* Put a layer of gravel or crushed rock in the bottom of the excavation, and install perforated drainage pipes if gravity drainage is practical.

* Cover the gravel or crushed rock in the floor area with a plastic vapor barrier before pouring a concrete floor.

* Coat the outer surfaces of roof and walls with bituminous waterproofing or other coating that has proved to be most effective in your locality.

* Backfill with gravel or crushed rock against the walls, to keep the soil from possibly becoming saturated. Saturated soil exerts hydrostatic pressure against walls, and may crack them and cause them to leak. In some areas it is more economical to cover a shelter's coated walls with a subsurface drainage matting (such as Enkadrain, manufactured and sold by BASF Corporation, Fibers Division, Enka, North Carolina 28728). This will eliminate the costs of backfilling with gravel or crushed rock.

NON-FLOATABLE SHELTERS

In most localities the water table usually is below the depth of excavation needed to build or install a belowground shelter. In some areas, however, after rainy periods the water table may rise until it is only a foot or two below the surface. Then a watertight shelter may float upward through the surrounding saturated soil, unless its weight plus the weight of its covering earth is sufficient to withstand its buoyancy. (In many places swimming pools are kept full to prevent them from being cracked by uneven buoyant forces if the water table rises.)

Dramatic examples of floating shelters were steel blast shelters, guaranteed by contractors to be watertight, that were installed under the lawns of some Houston, Texas homes shortly after the Cuban Missile Crisis. When the water table rose after heavy rains, these shelters came up to the surface like giant mushrooms, to the frustrated dismay of their owners and the satisfaction of anti-defense newspaper feature writers.

The most expensive permanent family fallout shelter described in a Federal Emergency Management Agency free handout (pamphlet H-12-1) is floatable. It is designed to be built of reinforced concrete covered by a flagstone patio only about 3 inches above the ground. Its 6-inch-thick concrete roof is covered by a total thickness of only 6 inches of sand and flagstone. Like the rest of FEMA's permanent shelters, no prototype of this approximately PF-40 shelter was built, nor is there any record of anyone actually having built this shelter. In contrast, the belowground shelter illustrated by Figs. 17.1 and 17.2 would not float even if it did not have assured gravity drainage of the surrounding soil through the perforated drain pipes in the gravel on which it rests, because this shelter is weighted down by the thick earth berm on its roof.

ADEQUATE, DEPENDABLE VENTILATION/COOLING

Basic facts that you need to provide adequate, dependable ventilation for a small or

medium sized shelter are given in Chapter 6, **Ventilation and Cooling of Shelters.** A good permanent shelter has two ventilation systems:

- The **primary ventilation system** of a small permanent shelter should utilize a manually operated centrifugal blower, or a homemade Plywood Double-Action Piston Pump. (See Appendix E.) A satisfactory air pump must be capable of supplying adequate outdoor air through an air-intake pipe, a filter, and an air-exhaust pipe. (See Figs. 17.1 and 17.2.) "Adequate outdoor air" for a small shelter means at least 15 cubic feet per minute per occupant for the cooler parts of the United States, and at least 30 cfm per occupant in most of the country. Most permanent shelters have centrifugal blowers that can not deliver an adequate volume of air in hot weather for each planned occupant.

For a medium sized permanent shelter, installing two or more manually powered air pumps is both more dependable and more economical than providing an emergency generator and its engine to supply power to an electric blower. The Swiss, who have made the world's best and most expensive per capita preparations to survive a war, use one or more hand-cranked centrifugal blowers to ventilate most of their shelters.

- The **multi-week and/or emergency ventilation system** of a permanent shelter that has an emergency exit should depend on a homemade KAP, made before a crisis and kept ready to use. (See Appendix B, **How to Make and Use a Homemade Shelter-Ventilating Pump, the KAP.)** By opening both the entrance and the emergency exit, the shelter is provided with two large, low-resistance openings through which a KAP can pump large volumes of air with minimum work.

Warning: Keep screen doors and/or screen panels ready to protect all openings against the swarms of flies and mosquitoes likely to become dangerous pests in fallout areas. Use your KAP to pump adequate air through screens. Insect screens greatly reduce natural ventilation, as the author first noted in Calcutta while a bed-ridden patient in a stifling hot ward of a hastily constructed Army hospital. Because there were no fans or blowers to pump in outdoor air or circulate the air inside, window screens were opened in the daytime when malaria mosquitoes were not flying. The doctors correctly concluded that the temperature reduction when the screens were opened helped the patients more than they were endangered by the entering filthy flies. Adequate ventilation is more important than protection from flies, but with a KAP and insect screens you can have both. Flies, mosquitoes, and other insects can be killed very effectively by occasionally spraying or painting screens and other alighting surfaces with water solutions of insecticides containing permithin and sold in many farm stores.

ADVICE ON VENTILATION OPENINGS AND FITTINGS

- Install ventilation pipes large enough to reduce resistance to airflow, thus increasing the volume of air that the shelter's pump can deliver. A shelter with a 200-cfm pump (such as the homemakeable Plywood Double-Action Piston Pump described in Appendix E) should have 5-inch galvanized steel pipe. The pumps that are installed in most family shelters deliver only about 100 cfm or less. Four-inch pipe is adequate for use with pumps this small, provided that the pipes have no more than two right-angle turns below each gooseneck. (A 90-degree L gives about as much resistance to airflow as 12 feet of straight pipe.)

- Make and install a gooseneck with its mouth about twice the diameter of the pipe, as indicated in Fig. 17.1. The purpose of such a gooseneck is to prevent more of the larger descending fallout particles from being pumped or blown into the shelter. For example, if 200 cfm of air is being pumped into a shelter through a gooseneck of 5-inch-diameter pipe with its mouth also 5 inches in diameter, the velocity of the air up into the mouth of the gooseneck is about 1,440 feet per minute, and sand-like spherical particles smaller than approximately 500 microns in diameter also are "sucked" up.[6] But if the 5-inch gooseneck's mouth is 10 inches across, then the upward air velocity is reduced to about 360 feet per minute, and only particles smaller than approximately 180 microns across are "sucked" up. Particles in the 180 to 500 micron-diameter range are relatively large and fall to earth in about 40 to 70 minutes from 35,000 feet, the base of the mushroom cloud of a 1-megaton explosion. (See Fig. 6.4.) These particles are very dangerous because their radioactivity has had little time to decay, and should be kept out of a shelter's ventilation system. Furthermore, large particles retained in a shelter's filter restrict airflow sooner than do small ones. (If an appropriately curved piece of 5-inch steel pipe cannot be found in a salvage yard or elsewhere, a good welder can use 5-inch steel pipe to make a substitute gooseneck with two 90-degree turns.)

- Do not use air intake hoods on a permanent shelter's pipes, because hoods are not as effective as goosenecks in preventing fallout particles from entering ventilation pipes. Also,

pumping a given volume of air through a hood is more work than pumping the same volume through a gooseneck with equal cross-sectional areas.

- Never install any screen inside a gooseneck or air intake hood, because spider webs and the debris that sticks to webs will greatly reduce airflow. The author saw a gooseneck with a blast valve built inside it; spider webs and attached trash on this blast valve had consequentially reduced the volume of air that this shelter's pump could deliver. Of course a screen is much more easily obstructed than a blast valve. Yet FEMA's widely distributed pamphlets on a permanent Home Fallout Shelter (H-12-1) and on a Home Blast Shelter (H-12-3) continue in successive editions to give detailed instructions for making an air intake hood with a screen soldered inside it. But these shelters that never have been built have much more serious weaknesses, including the likelihood that the aboveground parts of the ventilation pipes of the blast shelter would be bent over or broken off by blast-wind-hurled parts of buildings and trees, even in suburbia. (350 mph is the maximum velocity of the blast wind where the blast overpressure is 15 psi from a 1-megaton air burst.[6] The ventilation openings of the blast-tested expedient blast shelters described in Appendix D are much more likely to remain serviceable after being subjected to severe blast effects, because blast-protector logs are placed around their openings, that are only a few inches above ground level.)

PREVENTION AND CONTROL OF CONDENSATION

A shelter can be watertight, yet at certain seasons of the year its walls, ceiling, and floor can be dripping wet with water condensed from entering outdoor air. (This is a serious problem, except in arid parts of the West.) During the winter months a shelter and its surrounding earth get cold; then especially on some spring days the dew point of entering outdoor air is higher than the temperature of the shelter's interior surfaces. As a result, condensation occurs on those surfaces that are cooler than the dew point of the pumped-through air.

The most dramatic example that I have observed of the seriousness of this condensation problem was the dripping ceiling and wet walls of a reinforced-concrete, family-sized shelter that I inspected on an early spring day at the Civil Defence College in Yorkshire, England.

Such condensation also can occur in aboveground structures. Before World War II I had a 600-year-old bedroom in Queen's College, Oxford University. My bedroom's outer wall was made of solid limestone blocks about 15 inches thick, simply plastered and painted on the inside. On some spring days moisture condensed on the inside of the cold outer wall, ran down, and collected in little puddles on the floor. The occasional small coal fire in my adjacent study was barely sufficient to gradually evaporate the water and reduce my bedroom's humidity enough to prevent mold from forming. This often-repeated occurrence proves the inadequacy of merely keeping an electric light turned on for heat to prevent condensation inside an uninsulated shelter built in a cool, frequently humid locality.

Condensation and resultant 100 percent humid air can rust and eat away most steel pipes. Ventilation pipes should be made of galvanized steel or other materials that are undamaged by seasonal condensation and 100 percent humidity. In Connecticut I saw shelter ventilation pipes made of steel protected with two coats of marine paint; they were badly rusted only two years after installation.

Operating a dehumidifier with automatic controls is the most practical way for most people to prevent condensation and other dampness problems in a shelter during peacetime. Almost all of the Chinese shelters that I inspected in six cities are dual-use shelters and typically are equipped with large dehumidifiers. A small dehumidifier adequate for a family shelter can be bought from a dependable mail order company, such as Sears, for about $250 in 1987.

To save floor space and facilitate removal of water, a dehumidifier should be installed near a shelter's ceiling. Then water from the dehumidifier can be disposed of most easily through a pipe or tube providing gravity drainage, best to the outdoors, second best to the sewer. (After a nuclear attack the sewer system may become clogged and sewage may back up and flow into a belowground room having pipes that normally discharge into the sewer, and that lack check valves.) If the above mentioned ways of removing water are not possible, a sump and an automatic sump pump discharging water to the ground outdoors can solve the peacetime water disposal problem.

After an attack, electric power can be expected to fail and shelter humidity will have to be controlled as much as possible by ventilation with outdoor air. A simple way to learn when to ventilate a shelter to dry it was described in a Russian article on shelter management: Keep

several small cans of water in the shelter. They will be at about the same temperature as the shelter walls when the shelter is closed and is not being ventilated. If a filled can is exposed to outdoor air for about 10 minutes and moisture condenses on it (as a glass filled with an iced drink "sweats" on a humid summer day), do not ventilate the shelter. If no moisture condenses on the can, ventilate.

A WALK-IN ENTRANCE

Only a small fraction of permanent family shelters without a walk-in entrance have been kept in good condition for many years. Permanent family shelters with vertical or crawl-in entrances are found so inconvenient that the big majority of owners do not use them even for rotated food storage. In normal peacetime, most well informed Americans concerned with protecting their families conclude that only a shelter skillfully designed for dual use justifies the cost of building and maintaining it. Significantly, Chinese civil defense has come to the same conclusion regarding Chinese permanent public shelters: those that have been built, and that still are being built, are almost all useful both in peacetime and in wartime.

If a family can use its shelter without having to go outside and be exposed to rain, snow, cold, or night problems, its dual use shelter will be a more valuable peacetime asset than a shelter not directly connected to the house. Furthermore, a directly connected shelter can be entered more quickly in a crisis, and probably will reduce post-attack exposures to fallout radiation received by persons carrying things into the shelter, or by those moving about post-attack to protect the home. The main disadvantages of a directly connected shelter are that it usually provides poorer protection against heat, smoke and carbon monoxide if the house burns and that it is more expensive to build than an earth-covered shelter with an outdoor walk-in entrance, such as the one illustrated in Figs. 17.1 and 17.2.

AN EMERGENCY EXIT THAT ALSO PROVIDES A SECOND LARGE VENTILATION OPENING

Having an emergency exit in a fallout shelter is not as important as having one in a blast shelter, unless the fallout shelter is under or connected to a building. (Since buildings are likely to burn, it is important to have a means of escape.) However, an emergency exit makes any shelter more practical to live in than a shelter with only one large opening — especially in a heavy fallout area where it may be necessary to stay inside most of the time for weeks or months. Occupants of a shelter with only one large opening will not have adequate natural ventilation and will have to keep laboriously pumping air — at least intermittently — through the air-supply pipes to maintain liveable temperature and/or humidity conditions.

By opening both a shelter's entrance and its emergency exit, and taking measures to prevent the entry of rain, snow, and all but the smallest fallout particles (see Appendix F), natural ventilation will be adequate most of the time, except in hot, calm weather. With two large openings, a homemade KAP (see Appendix B) can be used to pump enough outdoor air through the shelter, with much less work than is required to pump less air with a relatively high-pressure pump through typical ventilation pipes.

A DEPENDABLE, HIGH-PROTECTION-FACTOR EMERGENCY EXIT

Occupants of a shelter with a dependable emergency exit will have less fear of being trapped if the main entry is blocked. If they open the exit, they also will be able to ventilate the shelter with natural ventilation through the entry and the exit, or with forced ventilation by operating a KAP.

To provide excellent radiation protection, a typical high-PF emergency exit is filled with sand. Such an exit has a bolted-on steel plate on its bottom inside the shelter, and an easily cut, waterproof, plastic-film covering over its top, which is a few inches below ground level. Obvious disadvantages of this typical sand-filled emergency exit include the difficulty of safely removing the bottom plate while sand is pressing down on it, and the impossibility of cutting the plastic film over the top of the exit without having fallout-contaminated earth fall on the person who does the cutting, and into the shelter room. Furthermore, if the earth covering the top of an emergency exit is frozen, occupants may be unable to break through it and get out.

An improved design of sand-filled emergency exit was conceived by Dr. Conrad V. Chester of Oak Ridge National Laboratory and in 1986 was further improved, built, and tested in a full-scale model by the author. As shown in Fig. 17.2, the sand in this 26 x 26-inch square vertical exit was supported by a piece of 3/4-inch exterior plywood, that should be of the previously mentioned rot-proof type, pressure impregnated with wood preservative.

In the center of this 25½ x 25½-inch plywood sand-support was an 8-inch-diameter hole covered with two thicknesses of strong nylon cloth.

The double thickness of cloth was firmly attached to the plywood by being folded over four 3/16-inch galvanized steel rods, that were stapled to the plywood with galvanized poultry-netting staples. (See Figs. 17.2 and 17.3.) The nylon cloth covering the hole can be easily and quickly cut with a knife, permitting sand to fall harmlessly into the shelter room.

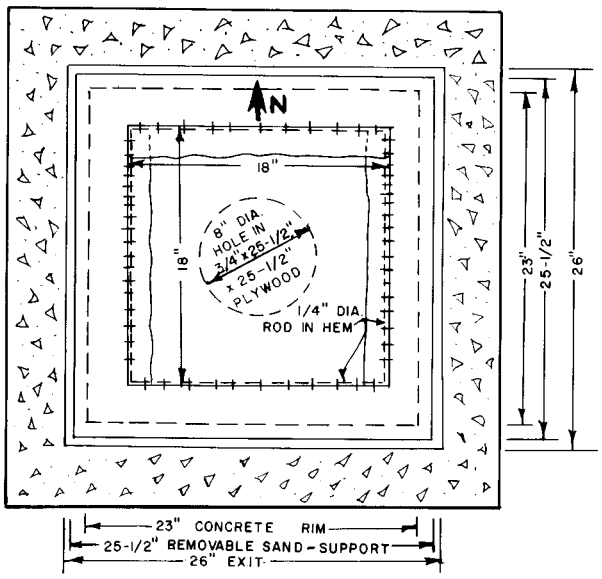


Fig. 17.3. Plan of Vertical Emergency Exit, Before Filling with Sand.

As shown in Figs. 17.2 and 17.3, the square 26 x 26-inch plywood sand-support rests on a 1½-inch-wide rim or ledge around the 23 x 23-inch square hole in the shelter's reinforced concrete roof slab. After a shelter occupant has cut out the nylon cloth covering the hole and all but about 30 lbs of sand has fallen or been pushed by his hand down into the shelter room, he can tilt the plywood sand-support up into a vertical position, and then turn it 45 degrees. The 26-inch width of the sand-support permits it to be easily lifted down through the 32.5-inch-long diagonal of the 23 x 23-inch square hole in the shelter's roof slab.

Note the North-pointing arrow on the plywood sand-support shown in Fig. 17.3. Because the exit of this shelter was not made perfectly square, the sand-support could be tilted most easily from its horizontal position into the vertical position if it was oriented so that its side marked "N" was to the north. A similar "N" arrow on the lower side of this sand-support enabled a man below it, after the exit's lid was tied down and before the exit was filled with sand, to position the sand-support for easy tilting and removal when the last of the sand was being cleared from this exit. The sand-support should be cut to fit the exit **after** the exit is completed, because it is difficult to build an exit exactly to specified dimensions.

The top of the emergency exit should be a few inches above the earth around it, to prevent rainwater on the ground from possibly running in. Securely cover the exit's top with a lid of 1/8-inch galvanized steel having a threaded plug-hole (cut from a steel barrel) welded over a hole cut in the lid's center. Such a lid can be closely fitted to the top of a concrete exit by oiling it and pressing it against the concrete before the concrete begins to set.

Before filling the exit with sand, while inside the exit tie the lid down on each of its four sides with nine loops of 3/32-inch nylon cord repeatedly tightened between four galvanized steel "⊓'s" welded to the lower side of the lid, and four "⊓'s" set in the shelter's walls and roof slab, as indicated in Fig. 17.2. Use pliers to tighten, stretch, and hold the nylon cord while making the loops. Then after the plywood sand-support is positioned in the bottom of the exit, the exit can be filled by pouring dry sand through the plug-hold in the steel lid. Finally, the plug-hole should be closed so that it cannot be opened, and then made waterproof. To make doubly sure that the lid will not rust, paint it with a cement paint, and then with whatever color outdoor paint you want.

A shelter occupant can cut out the nylon cloth covering the hole in the sand-support, remove all sand and the plywood sand-support from this exit, cut the four tightened nylon-cord multiple loops holding down the lid, push off the lid, and then climb up and step outside — all in less than 5 minutes, even if damp sand has been used to fill the exit. (To make removal of the sand more difficult, in his tests the author used damp sand that does not flow freely and makes it necessary to loosen it repeatedly, with one's hand and arm thrust up through the 8-inch hole in the plywood sand-support.)

In a well designed **blast** shelter this sand-filled emergency exit will provide excellent protection against severe blast. Blast tests have proved that a 1/8-inch steel lid (the equivalent of a blast door) the size of this exit's lid will withstand blast effects of at least 50 psi. Furthermore, sand arching will transfer blast loadings on the sand outward from the slightly downward deflecting plywood sand-support to its edges, and thence to the supporting reinforced concrete

rim or ledge around the 23 x 23-inch hole in the shelter's roof slab. (See Fig. 17.2.)

A small shelter with an emergency exit near its far end has additional advantages: It can be supplied with adequate natural ventilation most of the time, with easy forced ventilation by a KAP when forced ventilation is needed, and with daylight illumination. Means for attaining these advantages are described in Appendix F.

ADEQUATE STORAGE SPACE FOR ESSENTIALS

As will be shown in the following sections of this chapter, about 20 square feet of shelter floor area per family member is needed for shelter furnishings and to store adequate water for a month, a year's supply of compact dry foods, cooking and sanitary equipment, blankets, tools, and other post-attack essentials. Twenty square feet per family member also provides enough space per person to store winter clothing and footwear, camping equipment, and foods normally kept on hand and rotated as consumed in the course of ordinary family living. Additional space is needed if you plan to use your shelter as a workshop, or as a fallout shelter to save a few of your unprepared friends without endangering your own family.

SEATS/BUNKS/SHELVES

Seats and overhead bunks built like those specified in Fig. 17.4 and pictured in Fig. 17.5 enable more shelter occupants to sit and sleep more comfortably in less space than when using any other shelter furnishings known to the author. Note that the seat has an adjustable backrest. This backrest is similar to the fine-mesh nylon fishnet backrests tested in a prototype of an expensive blast shelter designed and furnished at Oak Ridge National Laboratory.

Shelter habitability tests have proved the need for backrests. Even some young German soldiers had painfully sore backs after sitting on ordinary benches during a 2-week shelter occupancy test.

Backrests should be installed in peacetime and kept ready for crisis use, rolled up against their upper attachments and covered. Then easily removeable storage shelves, if needed, can be installed between benches and overhead bunks.

To sit or sleep comfortably, pull the bedsheet forward and then sit on about the outer foot of the 2-foot-wide seat.

Although this 5-occupant shelter is illustrated with a bunk for each family member, it is

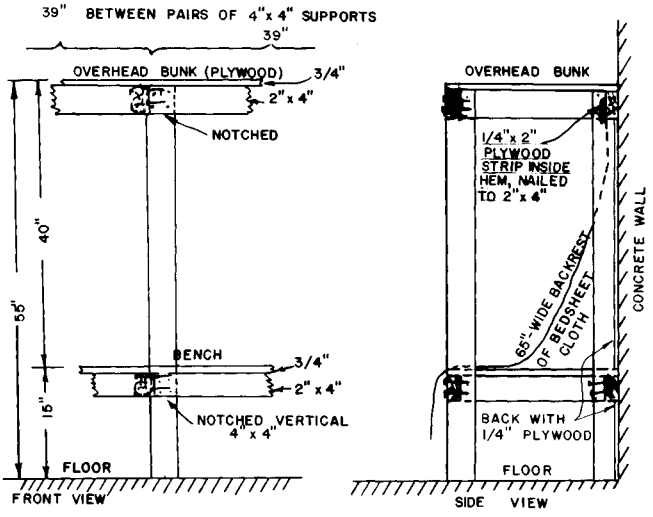


Fig. 17.4. Seat with Overhead Bunk Proportioned for a Shelter Room with a 7-Ft. or Higher Ceiling. A seat with a backrest should be 24 inches wide.



Fig. 17.5. Backrests of Bedsheet Cloth and 2-Inch-Thick Pads Make Sitting and Sleeping Comfortable.

prudent to count on stored supplies making some bunks unusable, and to realize that in a desperate crisis it might be hard to refuse shelter to an unprepared good neighbor. Note that with four persons seated on a 6.5-foot-long seat and one person on the overhead bunk, five persons can be quite comfortably accommodated on 25 square feet of floorspace, including plenty of room for the sitters' legs.

To store the most supplies in a shelter, you should install shelves after you know the heights of the items to be stored. Often the space between an overhead bunk and the ceiling can best be used by making easily removeable additional shelves.

WATER

- **Water needs:** Even most well-maintained shelters do not have enough water for prolonged occupancy. A permanent shelter should provide each occupant with at least 30 gallons of safe water — enough for an austere month, except in very hot weather.

- **Containers:** The most practical water container for shelter storage is a 5-gallon rigid plastic water can with a handle, a large diameter opening for quick filling and emptying, and a small spout for pouring small quantities. A 5-gallon water can of this type sells for about $5 in discount stores.

The plastic bottles that household chlorine bleach is sold in also are good for multi-year storage of drinking water, as are glass jugs. Plastic milk jugs are not satisfactory, because after a few years they often become brittle and crack.

Some shelter owners do not realize that, although a shelter can be kept dry in peacetime, except in the arid West its air is likely to become extremely humid after a few days of crowded occupancy. Very humid air soon softens and weakens cardboard containers of food and flexible water bags.

- **Disinfecting for multi-year storage:** To store safe water and keep it safe for years, first disinfect the container by rinsing it with a strong solution of chlorine bleach. Then rinse it with safe water before filling it with the clear, safe water to be stored. Next, disinfect by adding household bleach that contains 5.25% sodium hypochlorite as its only active ingredient, in the quantities specified in this book's Water chapter for disinfecting muddy or cloudy water. To 5 gallons, add 1 scant teaspoon of bleach. Finally, to prevent possible entry of air containing infective organisms through faulty closures, seal the container's closures with duct tape.

- **Making efficient use of storage space:** A 5-gallon rigid plastic water container typically measures 7 x 12 x 21 inches, including the height of its spout. Nine such 5-gallon containers can be placed on a 2 x 3-foot floor area. Twenty-seven 5-gallon containers, holding 135 gallons of water, can be stored on and over 6 square feet of floor if you make a water storage stand 24 x 42 x 48 inches high, built quite like the seat with overhead bunk described in the Seats/Bunks/Shelves section of this chapter. This easily moveable storage stand should have two plywood shelves, one 24 inches and the other 48 inches from the floor.

- **Using filled containers for shielding:** Filled 5-gallon water containers can be moved quickly to provide additional shielding where needed to increase the protection factor of all or part of a shelter. For example, near the inner door of the shelter illustrated by Figs. 17.1 and 17.2 the protection factor is less than 1000. But if enough filled water containers are placed so as to cover the door with almost the equivalent of an 18-inch-thick "wall" of shielding water, the PF of the part of the shelter room near the door can be raised to about PF 1000.

If a shelter has twenty-seven 5-gallon cans of water stored on and under the above-described 2-shelf water storage stand, then in less than 3 minutes 2 men can shield the shelter door quite adequately. All they have to do is take the 18 cans off the shelves, put 9 of them on the floor against the door and doorway, move the storage stand over the 9 door-shielding cans, and place the remaining 18 cans on the stand's 2 shelves.

Equally good doorway shielding can be provided by placing at least a 24-inch thickness of containers full of dense food, such as whole-grain wheat or sugar, against the doorway. Two 55-gallon drums of wheat, each weighing about 400 pounds, can be quickly "walked" on a concrete floor and positioned so as to shield the lower part of a doorway. Heavy containers on the floor can provide a stable base on which to stack other shielding material.

- **A water well:** The best solution to the water problem quite often is a well inside the shelter. In many areas the water table is less than 50 feet below the surface, and a 50-foot well, cased with 6-inch steel pipe, can be drilled and completed for about $2000. Well drilling should be done after the shelter excavation has been dug and before the concrete shelter floor has been poured. An in-shelter well would be of vital importance not only to the occupants of a family shelter, but later on probably to nearby survivors. Even if only a gallon or so an hour could be bailed from

a well too weak to be useful in peacetime, it would be a tremendous family asset post-attack. If infective organisms are found in water from a well drilled to provide water during and after an attack, safe water for months can be assured by merely storing a few gallons of household chlorine bleach.

If enough water for worthwhile peacetime use can be pumped from a well, install a submersible electric pump, with plastic pipe in the well. Then in an emergency the pipe and the attached pump can be pulled by hand out of the well, with only a saw being needed to cut off lengths of the plastic pipe as it is pulled. After the well casing has been cleared of pump, pipe and wires, a homemade 2-foot-long bail-bucket on a nylon rope can be used to draw plenty of water. (See Chapter 8, Water, for instructions.)

- **Local water sources:** Most Americans' normal piped water would not run for months after a large nuclear attack. A month's supply of water stored in your shelter should be adequate, because, even if your area has heavy fallout, in less than a month radioactive decay will make it safe to haul water from nearby sources.

An important part of your shelter preparations is to locate nearby wells, ponds, streams, and streambeds that when dry frequently have water a foot or two below the surface. The author has found that digging a water pit in an apparently dry streambed often supplies enough filtered water to satisfy several families' basic needs. To keep the sides of a water pit dug in unstable ground from caving in, you should drive a circle of side-by-side stakes around the outside of your planned pit before starting to dig. With more work and materials, you and other survivors needing filtered water could dig a well like the Chinese water source shown on page 71. If you are in a fallout area, before drinking water from a water pit you should filter it through clayey soil to remove fallout particles and dissolved radioactive isotopes, as described in the Water chapter. Of course it is prudent to chlorinate or boil all surface and near-surface water after it has been filtered.

FOOD

- **Advantages of a one-year supply:** A family that expends the money and work to build and provision its own shelter should store a year's supply of long-lasting foods. If post-attack conditions enable you to continue living and making a living near your home, having a year's food supply will be a tremendous advantage. And if your area is afflicted with such dangerous, continuing fallout radiation and/or other post-attack conditions that surviving unprepared residents are soon forced to evacuate to better areas, then your and your family's chances will be better if hunger does not force you to move during the chaotic first few months after a nuclear attack.

- **Costs of a one year food supply for a family shelter:** Table 17.1 shows the wide range of 1987 costs of the basic survival foods for multi-year storage that are listed and explained on page 88.

The delivered costs listed in the right hand column include UPS shipping charges in the nearest and least expensive of UPS's 8 zones. For UPS shipping costs to the most distant points in the 48 states, add 34 cents per pound delivered.

All the foods in this survival ration, if stored in moisture-proof and insect-proof containers (the non-fat milk powder should be in nitrogen-packed cans), will provide healthful nutrition for at least 10 years. The exception is the multi-vitamin tablets, which should be replaced every 2 or 3 years, depending on storage temperature. So a family that spends about $300 per member on such a one year survival ration can consider that each of its members has been covered by famine insurance for $30 a year.

Scurvy will be the first incapacitating, then lethal vitamin deficiency to afflict unprepared, uninformed Americans. A multi-vitamin tablet contains enough vitamin C to fully satisfy the daily requirement. However, a prudent shelter owner also should store vitamin C tablets, that keep for years. One hundred 500-mg generic vitamin C tablets — 50,000 mg of vitamin C — in 1987 typically cost about $1.20 in a discount store; a 10 mg daily dose prevents scurvy. After a nuclear war in some areas vitamin C will be worth many times its weight in gold.

- **Sources of the basic foods listed in Table 17.1:**

  * **Wheat:** If you live in a wheat producing area, the least expensive sources of ready-to-store wheat usually are local seed-cleaning firms. A hundred pounds or more of hard wheat, dried, bagged, and ready to store in moisture proof containers, costs about 10 cents a pound. (Today the wheat farmer receives about 4.5 cents a pound for truckloads, usually straight out of the field, not dry enough to store except in well ventilated granaries, and containing trash that makes weevil infestations more likely.) In some communities a few stores sell big bags of dry, cleaned hard wheat for 20 to 35 cents a pound.

Shelter owners who are unable or unwilling to obtain wheat from such sources can buy high

Table 17.1. A basic one-year survival ration for one adult male.

Component	Ounces per day	Pounds per year	Range of 1987 retail prices in dollars per pound, FOB, or picked up	Range of 1987 costs in dollars for a one year supply, FOB, or picked up	Range of 1987 costs in dollars for a one year supply delivered and in containers for multi-year storage
Whole-kernel hard wheat	16	365	0.10 to 0.40	36.50 to 135.00	56 to 175
Beans, pinto	5	114	0.25 to 0.79	28.50 to 90.11	38 to 110
Non-fat milk powder	2	46	1.68 to 3.86	77.28 to 177.56	83 to 184
Vegetable oil	1	23	0.36 to 0.57	8.28 to 13.11	9 to 14
Sugar	2	46	0.25 to 0.30	11.50 to 13.80	16 to 20
Salt, iodized	1/3	8	0.17 to 0.20	1.36 to 1.60	2 to 3
Multi-vitamin tablets (low generic, and an expensive brand)	1 per day	365 per year	1.3 to 11.8 cents per tablet	4.75 to 43.07	6 to 44
Total $ costs					$210 to $550

protein hard wheat at higher prices from health food stores and a few mail order companies. The lowest mail order FOB price known to the author for hard western wheat in 1990 is $3.17 for 10 pounds, in a vacuum-packed metallized plastic bag similar to the containers used for some U.S. Army combat rations. This long-lasting wheat, as well as other grains and legumes, is sold by Preparedness Products, 3855 South 500 West, Salt Lake City, Utah 84115. Another reliable mail order source of wheat and other dry foods packaged for multi-year storage is The Survival Center, 5555 Newton Falls Rd., Ravenna, Ohio 44266.

* **Beans,** like wheat, in many communities can be purchased from local farmers' co-ops or local stores at much lower delivered cost than from mail order firms. In one small Colorado town the co-op sold 25 pounds of pinto beans in a polyethylene bag for $11.25—45 cents a pound. Local supermarkets sell bulk pinto beans for around 60 cents a pound.

* **Non-fat milk powder** in 1990 is sold nationwide in the larger cardboard packages for around $2.85 per pound. A better buy for multi-year storage is the instant non-fat milk powder sold by Preparedness Products. This Mormon-owned firm's 1990 FOB price is $57.95 for a case of 6 nitrogen-packed cans, containing a total of 22.5 pounds. The author bought a case three years ago and found this non-fat instant milk powder to be excellent. At $2.58 a pound, plus UPS shipping charges, the cost is considerably less than for comparable milk powder packaged for multi-year storage and sold by other companies.

* **Vegetable oil, sugar, salt,** and **multi-vitamin tablets** are best bought at discount supermarkets. In cities such stores often sell large plastic containers of vegetable oil as "loss leaders" to attract customers, at prices as low as wholesale. Vegetable oil prices in small communities typically are much higher. For an economical survival ration, buy the lowest priced vegetable oil. Remember that one of the worst post-attack nutritional deficiencies will result from chronic shortages of fats (including oils), and that babies and little children cannot survive for a year on a diet of only grains and beans, with no oil or fat. See the Food chapter.

● CAUTIONS: Typical health food stores and most firms that specialize in survival foods sell basic foods at high prices, especially grains, beans, and milk powder. Investigate several other sources before buying.

To make sure that an advertised "one year supply" of survival foods actually will keep an adult well nourished for a whole year, require the seller to inform you **by mail** what his "one year supply" provides a typical adult male in: (1) calories, k cal; (2) protein, g; and (3) fat, g. Then you can use the values in the "Emergency Recommendations" column in Table 9.1 on page 84 to determine whether the advertised "one year supply" is adequate.

- **Transitional foods:** The emotional shock of suddenly being forced by war to occupy your shelter will be even worse if you have to adapt suddenly to an unaccustomed diet. It would be a good idea to occasionally practice eating only your survival rations for a day or two, and to store in your shelter a two week supply of canned and dry foods similar to those your family normally eats. Then it will be easier if war forces you to make the changeover. Of course the transitional foods that you store should be rotated and replaced as needed, depending on their shelf lives.

- **A hand-cranked grain mill:** Whole kernel grains and soybeans must be processed into meal or flour for satisfactory use as principal components of a diet. If unprepared America suffers a nuclear attack, unplanned, local food reserves and/or famine relief shipments will consist mostly of unprocessed wheat, corn, and soybeans. Then a family with a manual grain mill will have a survival advantage and will be a neighborhood asset.

Many health food stores at least have sources of hand-cranked grain mills. Mills with steel grinding plates are more efficient and less expensive than "stone" mills. A mail order firm that still sells hand-cranked grain mills of a make that the author has bought and found to be well made and efficient is Moses Kountry Health Foods, 7115 W. 4th N.W., Albuquerque, New Mexico 87107. It sells a serviceable Polish mill (Model "OB" Hand Grain Mill) for $35.73 FOB, plus UPS shipping charges. This mill cranks easily and grinds wheat into coarse meal or fine flour more efficiently than any of the American manual grain mills that the author has bought and used over the decades. Apparently manual grain mills no longer are manufactured in the U.S. Before buying a grain mill be sure to learn whether it grinds corn, our largest food reserve. In 1987 the author bought an advertised West German mill. Only after receiving it by mail order did he learn by reading the accompanying directions that it is not made for grinding corn.

COOKING AND HEATING

- **Safety precautions:** The first rule for safe cooking and/or heating in a shelter is to do it as near as practical to the exhaust opening. If the fire is under an exhaust pipe, install a hood over the fire. Operate the shelter ventilating pump when cooking, unless a natural airflow out through the exhaust opening can be observed or felt. Keep flammable materials, especially clothing, well away from any open fire.

- **Hazardous fuels:** Charcoal is the most hazardous fuel to burn in confined spaces, because it gives off much carbon monoxide. In a crowded shelter there are obvious dangers in using the efficient little stoves carried by backpackers and in storing their easily vaporized and ignited fuels.

- **"Canned heat":** These convenient fuels are expensive. Sterno, widely used to heat small quantities of food and drink, typically retails in 7-ounce cans for what amounts to about $9.00 per pound.

- **Wood:** The safest fuel to burn in a shelter is wood, the most widely available and cheapest fuel. Furthermore, wood smoke is irritating enough to usually alert shelter occupants to sometimes accompanying carbon monoxide dangers. Scrap lumber cut into short lengths, made into bundles and stored in plastic bags, occupies minimum space and stays dry. Keep a saw and a hatchet in your shelter.

- **Bucket Stove:** The most efficient, practical and safe stove with which to cook or heat for weeks or months in a family shelter is a Bucket Stove, that burns either small pieces of wood or small "sticks" of twisted newspaper. (See the Food chapter.) Especially if you believe that you may have to live in your shelter for months or that your normal fuel will not be available after a nuclear attack, you should make and store at least two Bucket Stoves.

- **An improved Fireless Cooker:** To save a great deal of fuel and time, particularly with slow-cooking grains and beans, make a very well insulated Fireless Cooker similar to the expedient one described on page 82 of the Food chapter. Make a plywood box, first measuring carefully to insure that, when completely lined with 4 inches of styrofoam, the styrofoam will fit closely around a large, lidded pot wrapped in a bath towel. An excellent Fireless Cooker is a war survival asset that also is useful for peacetime cooking.

(To boil about twice as much wheat flour-meal in a given pot as can be boiled when making wheat mush, and to use the minimum amount of water and fuel, salt a batch of the flour-meal, add enough water while working it to make a stiff dough, then make dough balls about 1½ inches in diameter, and roll them in flour-meal. Drop the wheat balls into enough boiling water to cover them, and boil at a rolling boil for 10 minutes. Then put the boiling-hot pot in a well insulated Fireless Cooker for several hours. Corn balls can be made and boiled in this

manner, also without the almost constant stirring required when boiling a mush made of home-ground flour-meal.)

- **A sturdy work bench:** In the corner under the emergency exit build a work bench, secured to a wall, on which to cook and to which you can attach your grain mill. A bench 36 inches high, 42 inches wide, and 30 inches deep will serve. (The other corner at the air-exhaust end of the shelter should be the curtained-off toilet and bathing area.)

- **Very warm clothing, footwear, and bedding:** Heating a **well ventilated** shelter usually is unnecessary even in freezing weather if the occupants have these essentials for living in the cold, or if they have the materials needed to make at least as good expedient means for retaining body heat as are described in Chapter 15. The author has felt the warm hands of little Chinese children wearing padded clothing while living in their below freezing homes, where there was scarcely enough straw, grass, and twigs to cook with. If you store plenty of strong thread and large needles in your shelter, you can make warm clothing out of blankets — as some frontier settlers did to survive the sub-zero winters of Montana.

LIGHT

- **White paint:** To make a little light go a long way, paint the walls, ceiling, floor, and furnishings pure white.

- **Candles:** The most dependable and economical lights for a family shelter are long-burning candles. The best candle tested by the author is the 15-hour candle manufactured by the Reed Candle Company of San Antonio, Texas and sold by the millions in New Mexico each Christmas season for use in outdoor decorative "luminarias". This votive-type, short candle is not perfumed and has a wick supported by a small piece of metal attached to its base, so that the wick remains upright and continues to burn if the wax melts and no longer supports it. If burned in one of the candle-lamps described below, this candle gives enough light to read by for 15 hours.

The author has been able to find only one mail order source of 15-hour candles like those sold by the millions in New Mexico: Preparedness Products, 3855 South 500 West, Salt Lake City, Utah 84115. A case of 144 candles sells for $49.00, FOB in 1990. When UPS shipping charges are added, the delivered cost is between 35 and 40 cents for each 15-hour candle, depending on the distance shipped.

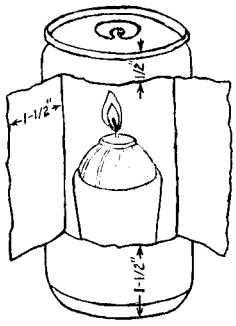
Persons who stock a permanent shelter should realize that after a nuclear war fats, oils, paraffin, and all other sources of light will be in extremely short supply for at least many months. Light at a delivered cost of about two cents per hour will be a bargain blessing.

* The second-best shelter candle tested by the author is a standard Plumber's Candle, that retails for about 60 cents in many stores nationwide, and that burns for about 10 hours with a brighter flame than a votive-type candle.

Two types of expedient candle-lamps were proved by multi-day tests to be the most practical:

* The best expedient candle-lamp is made of a 1-pint Mason jar, identical to the cooking-oil lamp pictured on page 102 of the Light chapter except for the substitution of a short candle for the oil and wick. To make a stable candle base on a glass jar's rounded bottom, cover it with hot candle wax. To be able to light the candle and then put it inside the glass jar, make tongs out of an 18-inch length of coathanger wire bent in the middle, with each of its two ends bent inward 90 degrees and cut off to make 1/4-inch-long candle grippers.

* The second-best candle-lamp is made by cutting a standard aluminum pop or beer can, as illustrated. Use a **sharp** small knife. To make a stable base for a short candle, put enough sand across the can's rounded bottom to barely cover its center. The first candle burned will saturate and then harden the sand, making a permanent candle base or holder.



Caution: Although candles are the safest non-electric lights for shelter use, they produce enough carbon monoxide to cause headaches in a poorly ventilated, long-occupied shelter. In a 2-week habitability test of a family shelter in Princeton, the father and mother did not smoke, yet they had persistent headaches. Specialists later concluded that their headaches were caused by the small amounts of carbon monoxide produced by the candles used both for light and to heat food and drink.

- **Expedient lamps:** The very economical lamp that burns cooking oil in a 1-pint glass jar is the

better of the two expedient lamps pictured on page 102. For use in a shelter, however, long-burning candles, that are serviceable after decades of storage, are more practical. Among the disadvantages of expedient lamps is the fact that untreated, soft cotton string needed to make excellent wicks is no longer available in some communities, and making wire-stiffened wicks is a time consuming chore.

- **Other light sources:** See the Light chapter.

NYLON HAMMOCK-CHAIRS

To enable the maximum number of additional people to occupy a shelter for days to months, nylon Hammock-Chairs should be made before a war crisis arises, and should be kept stored for emergency use. The best field-tested model for use in shelters that are at least 7 feet wide is similar to the expedient Hammock-Chair described on pages 120 through 124, is made of strong nylon cloth, and is 40 inches wide by 9 feet long along its center line, with each of its long sides being 8 feet-4 inches long. At each end is a curved hem 3½ inches wide, through which a loop-ended nylon hammock rope is run, to draw the slung hammock into a boat-like, secure shape with adequate head and shoulder room. The breaking strength of a hammock rope should be at least 600 pounds.

To attach the nylon ropes that support the suspended chair's two "arms," a loop of nylon webbing, or of folded and stitched nylon cloth, should be sewn to each side edge of the hammock 52 inches from the end of the hammock that will serve as the top of the back of the chair. See the illustrations on page 124. Especially in permanent family shelters, support points both for the hammocks, and for the hammocks when they are converted into suspended chairs, should be made when the shelter is being built.

OFTEN OVERLOOKED SANITATION AND OTHER SHELTER NEEDS

Store enough soap to last your family for at least a year. After a major nuclear attack the edible fats and oils, used in past generations to make soap, will almost all be eaten. Production of detergents is based on inter-dependent, vulnerable chemical industries not likely to be restored for years.

A chemical toilet would help bridge the gap between modern living and surviving in a crowded shelter. For months-long occupancy, however, a more practical toilet is likely to be a 5-gallon can with a seat, a plastic trash bag for its removable liner, a piece of plastic film for its tie-on cover, and a hose to vent gasses to the outdoors. See page 104. Store at least 200 large plastic trash bags.

The author knows from his experiences in primitive regions that using anything other than paper in place of toilet paper or cloth is hard to get accustomed to. A hundred pounds of newspaper, stored in plastic trash bags to prevent it from getting damp, takes up only about 3 cubic feet of storage space and would be useful for many purposes.

Keep several thousand matches, in Mason jars, so that they will be sure to stay dry even if your shelter becomes very humid post-attack.

Store most of your radiation monitoring instruments in your shelter, along with paper and pencils with which to keep records of radiation exposures, etc. A steel or reinforced concrete shelter should have a transistor radio with extra batteries, and a vertical pipe through which an antenna can be run up to improve reception.

No one can remember all the needed survival facts and instructions given even in this one book, so keep *Nuclear War Survival Skills* and other survival guidance in your shelter, and also other books that you believe may improve your family's morale and survival chances.

PRACTICE SHELTER LIVING

A family that spends a weekend living in its completed small shelter will learn more about unrecognized shelter needs — and more about each other — than members are likely to learn if they all read civil defense information for two whole days. Furthermore, after this educational experience family members old enough to have nuclear fears will know for sure that anti-defense activists are talking nonsense when they maintain that if most Americans had shelters they would become less heedful of nuclear war dangers and more likely to support aggressive leaders.

Appendix E

How to Make and Use a Homemade Plywood Double-Action Piston Pump and Filter

THE NEED

Ventilating pumps—mostly centrifugal blowers capable of operating against quite high resistance to airflow—are used to force outdoor air through most high-protection-factor fallout shelters and through almost all permanent blast shelters. Low-pressure ventilating devices, including ordinary bladed fans and homemade air pumps such as KAPs and Directional Fans, cannot force enough air through a permanent shelter's usual air-supply system consisting of pipes, or of pipes with a blast valve, a filter, and the valves needed to maintain a positive pressure within the shelter.

Manually cranked centrifugal blowers, or blowers that can either be powered by an electric motor or be hand-cranked, are the preferred means of ventilating permanent shelters from Switzerland to China. The main disadvantages of efficient centrifugal blowers are:

1. They are quite expensive. For example, in 1985 a good American hand-cranked blower, that pumps only about 50 cubic feet per minute (50 cfm) through a shelter's pipes, blast valve and filter, retails for around $250. An excellent foreign blower that enables one man to pump somewhat larger volumes sells for about twice as much.
2. Not enough centrifugal blowers could be manufactured quickly enough to equip all shelters likely to be built during a recognized crisis threatening nuclear attack, and lasting for weeks to several months.

Therefore, there is need for an efficient, manually operated, low-cost ventilating pump that:

1. Can pump adequate volumes of outdoor air through shelter-ventilating systems that have quite high resistances—up to several inches water gauge pressure differential.
2. Will be serviceable after at least several weeks of continuous use.
3. Can be built at low cost in home workshops by many Americans, using only materials available in most towns.
4. Could be made by the millions in thousands of shops all over the U.S., for mass production during a recognized prolonged crisis, using only plywood and other widely available materials.

To produce such a shelter ventilating pump, during the past 20 years I have worked intermittently designing and building several types of homemade air pumps. However, until I was traveling in China as an official guest in October 1982 and saw a wooden double-action piston pump being used, I did not conceive or come across a design that I was able to develop into a shelter-ventilating pump that meets all of the requirements outlined above. Now I have made and tested a simple homemade Plywood Double-Action Piston Pump, described below, that satisfies these requirements. Three other persons have used successively improved versions of these instructions to make this model, and several others have contributed improvements.

HOW A PLYWOOD DOUBLE-ACTION PISTON PUMP WORKS

Fig. 1 pictures the box-like test model described in these instructions.



Fig. 1. Plywood Double-Action Piston Pump, with manometer attached for tests.

Fig. 2 illustrates a vertical section through a slightly improved model, and shows the 12x12-in. plywood piston being pushed from right to left, causing air from the outdoors to be "sucked" down the open air-supply duct in the top of the pump, then down to the right through the open valve in the airtight frame (that is above and near the right end of the PARTITION), and on down into the lower-pressure area behind the leftward-moving piston.

Because the air to the right of the leftward-moving piston is at a lower pressure than the air in the shelter room, the exhaust valves in the front end (the handle end) of the pump are held closed.

During this half of the pumping cycle, the higher-pressure air in the part of the pump's square "cylinder" to the left of the leftward-moving piston opens the air-exhaust valves in the back end of the pump, and fresh air is forced out into the shelter room. The higher-pressure air to the left of the valve in the airtight frame (that is above the left end of the PARTITION) keeps this valve closed, while the lower-pressure air to the right of this valve helps keep it closed.

When the piston is pulled to the right, all of the valves shown closed are quickly opened, and all shown open are quickly closed. Then fresh air is forced into the shelter room through the opened exhaust valves in the front end of the pump.

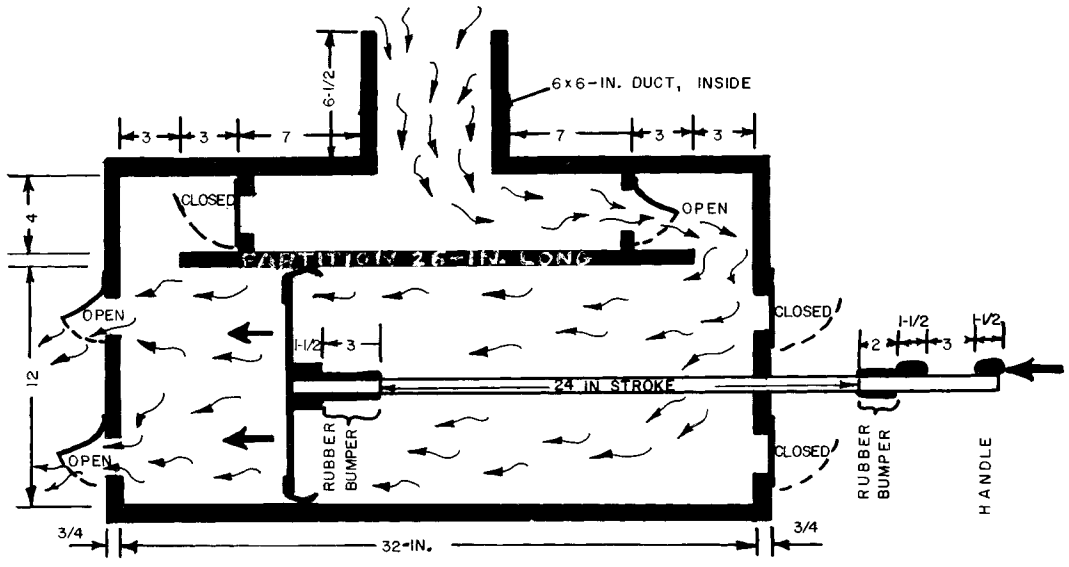


Fig. 2. Vertical Section of the Double-Action Piston Pump showing its square piston being pushed to the left.

PERFORMANCE TESTS

The volumetric and durability tests summarized below are proof that this homemade Plywood Double-Action Piston Pump is better than most hand-cranked centrifugal blowers for supplying a shelter with outdoor air through typical air-intake and exhaust pipes—especially when the ventilation system contains a filter and/or blast valves. The filters that give the best protection, Chemical Biological Radiological (CBR) Filters, have quite high resistance to airflow, as do commercial blast valves that close quickly enough to protect filters.

1. **Volumetric tests.** Because the rapidly pulsating airflows into and out of a piston pump are very hard to measure accurately with an air velocity meter, I made an inflatable cylindrical bag of 2-mil (0.002 inch) polyethylene film; the fully inflated volume of this bag was 256 cubic feet. The bag was suspended on a horizontal strong cord running through its length. A short tube 62 inches in circumference connected the back end of the pump (that is opposite the operator's end) to the suspended bag. Bag and pump were in a below ground shelter that normally has essentially motionless air. See Fig. 1.

Since this type of pump exhausts equal volumes of air from each of its two ends, the total cubic feet per minute (cfm) that it pumps equals twice the cfm that it exhausts into the shelter from one of its ends. See Fig. 1, that shows the pump attached with "C" clamps to a small steel table and being used to pump air into the 256 cubic foot suspended bag.

I measured the pressure differences against which the pump was operated. In a shelter these differences typically are caused by the resistance to airflow in pipes, valves, and a filter. I measured pressure differences in inches water gauge (1 in. w.g. = 0.036 psi) with the small-tube manometer attached to the side of the pump. To produce various pressure differences for several tests, I nailed a piece of plywood over the top of the air-intake duct, so as to produce different sized openings; in most tests I placed different layers of filter materials in a filter box that was fitted airtight over the 6 x 6-in. air-supply duct on the top of the pump. See Fig. 3. (This low-resistance filter removes practically all fallout particles of wartime concern, and also most infective aerosols that may be used in biological warfare. See "Making and Using a Homemade Filter Box and Filter", by Cresson H. Kearny, October 1985.



Fig. 3. Pump with Homemade Filter (20 x 20 x 8-inches inside dimensions) connected airtight on top of the pump's 6 x 6-inch air-intake duct.

The best centrifugal blowers that I have seen or heard about are those manufactured by a Finnish company, Temet Oy. (I cranked a Temet Oy blower in an Israeli shelter used for testing ventilation equipment; the Finnish centrifugal blower was better than Swiss, German and captured Russian blowers also undergoing tests.) Therefore, in Table 1 a few of the volumetric tests of my best model Plywood Double-Action Piston Pump (powered by one and two men) are compared with performance data furnished by Temet Oy for its centrifugal blower when cranked by two men. I have converted Temet Oy's metric units into the common American units.

In Table 1 the pressure difference of 4.3 inches water gauge is the resistance to airflow that Temet Oy realistically gives as typical of a well designed shelter ventilation system of pipes, valves and blower plus a Chemical Biological Radiological (CBR) filter. Temet Oy gives 2.0 inches water gauge as typical of the same ventilation system with only a low resistance dust filter. The much larger volume pumped by the Double-Action Piston Pump when a CBR filter is used (as compared to the cfm pumped by this very good centrifugal blower) is typical of the reduced effectiveness of even the best centrifugal blowers at high pressure differences.

TYPE OF PUMP	PRES. DIFF. (in. w.g.)	CUBIC FEET PER MINUTE	HORSE-POWER
Double-Action Piston Pump			
one man	4.9	134	?
two men	4.3	182	?
Temet Oy Centrifugal Blower			
two men	4.3	90	0.15
Double-Action Piston Pump			
one man	2.3	172	?
two men	2.3	208	?
Temet Oy Centrifugal Blower			
two men	2.0	300	0.18

Table 1. Comparison of Plywood Double-Action Piston Pump with Temet Oy Centrifugal Blower.

In areas devastated by a nuclear explosion, the typical very dusty conditions are likely to result in filters soon becoming dirty and higher in resistance to airflow. Then the greater effectiveness of a piston pump for ventilating a shelter with a high-resistance air-supply system will be even more important than when its filter is clean.

The horsepower requirements of my pump have not yet been measured. However, based on the calculated air pressure on the 12 x 12-in. piston of 22.3 lbs. when the pressure difference was 4.3 in. w.g. (0.155 psi), when two pumpers were making 52 strokes (cycles) per minute while pumping 182 cfm, the horsepower delivered was about 0.14 HP without allowing for friction and the losses of power due to reversals in the directions of piston movements. I estimate that the actual horsepower delivered by the two pumpers (I, a 69 year old with a stiff back in 1983, and a 15-year-old boy) was somewhat less than 0.2 HP. A man in good condition can work for hours delivering 0.1 HP.

When comparing machines powered by human muscles, what muscles are used and how they are used are often as important as are the horsepower requirements. Leg muscles are more efficient and are much stronger than arm muscles. Arm muscles are used much more in cranking a blower than in pushing and pulling the piston of a properly designed reciprocating piston pump back and forth horizontally. See Fig. 3. If this double-action piston pump is placed at a height above the floor so that its handle is approximately at the height of a standing operator's elbows, then the operator can do most of the work with his legs. See Fig. 3. He efficiently moves his body back and forth for over a foot, while moving his hands and forearms horizontally for slightly less than a foot relative to his body. To deliver the same horsepower by cranking a blower uses less efficient muscles inefficiently, and is much more tiring.

As shown in Table 2, the volumetric efficiency of my best model is good for a shelter-ventilating pump. The volumetric efficiency of a piston pump (a positive displacement pump) is found by dividing the cfm actually pumped by the theoretical maximum cfm at the same pumping rate and the same pressure difference, assuming all piston strokes are full length, that all valves open and close instantaneously, and that there is no leakage. Table 2 shows that the greater the pressure difference, the lower the efficiency—as one would expect, because of increased leakage.

PRES. DIFF. (in. w.g.)	STROKES PER MINUTE	cfm	EFFICIENCY
4.0	36	122	84.0%
2.6	45	160	89.0%
0.7	51	188	92.0%
0.4	54	202	94.0%
0.2	55	208	94.5%

Table 2. Volumetric Efficiencies of Double-Action Piston Pump Operated by One Man.

2. **Durability tests.** Finding a homemakeable method to seal the moving piston so as to assure at least one month of continuous efficient pumping was the most difficult problem. Various rubber seals attached to the edges of the piston were unsatisfactory, and aluminum sheetmetal strips (shaped and attached like the galvanized steel sheetmetal strips used in this model) wore out in less than a week, even when oiled every 24 hours.

To save money during weeks of continuous durability testing, the pump was operated by an electric motor that powered a pulley drive that turned a 2-foot-diameter pulley having an attached 40-in.-long steel pitman with a hinged connection to a horizontally-sliding bar connected to the handle of the pump's wooden piston rod. See Fig. 4.



Fig. 4. Mechanized Drive Used in Weeks-Long Durability Tests.

After pumping for 380 hours (15.83 days) at 44 strokes per minute against a pressure difference of 2.3 in. w.g., the worst worn spot on any of the **30-gauge** steel sheetmetal sealing strips on the piston was reduced in thickness from its original 0.0155 in. to 0.0145 in. This worst-spot wear of 0.001 in. is only about a 6% reduction in thickness. The flap valves functioned as well as when new, and appeared unworn.

I conclude that this pump would be serviceable after several months of continuous use—provided it is lubricated after every 24 hours of actual use, as in this durability test. In this test I lubricated the piston, its "cylinder's" four walls, and its rod with Lubriplate No. 105, "the original white grease". This non-sticky "grease-type lubricant" is used extensively, especially to lubricate internal combustion engines before first starting up. Another builder of this model pump found Siloo White Lube, an all-purpose lithium grease, the best of the lubricants that he tested. Judging from my prior durability tests, a very light oil applied daily serves reasonably well. Ordinary bearing grease is unsatisfactory.

MATERIALS

The following materials (that cost about $65, retail in 1985) are needed to make and operate the best model of this pump:

Plywood, 3/4-in. exterior: one 4 x 8-ft. sheet (finished on one side, unwarped).

Plywood, 3/8-in. exterior: 1/4th of a 4 x 8-ft. sheet (finished on one side, unwarped). (Second choice: 1/4-in. exterior plywood).

Oak board, 3/4 x 1-3/4 in., **straight**, well seasoned, 4 ft. long, to make the piston rod. (If oak or other very strong wood is not available, use a **straight** fir or pine board.)

Fir or pine board, about 3/4 x 1-3/4 in., 8 ft. long, to make the piston-rod handle, etc.

28-gauge or lighter galvanized-steel flashing (sold by lumber yards for roofers), no thicker than 0.016 in.; or galvanized steel or flashing no thinner than 0.012 in. Or 30 gauge galvanized steel sheetmetal available in some sheetmetal shops. (Sheetmetal thicker than 0.016 is not springy enough for making this pump's near-equivalent of piston rings.) Best to go to a sheetmetal shop and have 3 strips cut, each 3 in. wide and about 30 in. long.

Screws, round-headed, zinc-plated wood screws:
- 22 each of No. 12 (2-in. long, 12/32 in. dia.), with flat washers
- 10 each of No. 10 (1-1/2 in. long, with flat washers)
- 15 each of No. 6 (3/4 in. long, with flat washers)

Nails, 4-penny (1-1/2 in.), best cement-coated: 1/4 lb.

Nails, 3-penny (1-1/4 in.), galvanized: 1/4 lb.

Staples (if an oak board for the piston rod is not available), No. 17, 3/4-in., galvanized): 1/4 lb.

Tacks, No. 6 upholstery, (1/2-in. long): a small container.

Tacks, No. 3 upholstery (3/8-in. long): a small container.

Felt, weather stripping, 5/8-in. wide: 10 ft.

Tape, silver duct tape, 2-in. wide: a small roll.

Tape, masking tape, 3/4-in. wide: a small roll.

Adhesive, waterproof: "Liquid Nails", or other all purpose construction adhesive: one approx. 11-oz. tube (for use in caulking gun).

Epoxy, 5-minute: 2 tubes.

Rubber cement: a small tube.

Sealer (such as polyurethane clear finish, to reduce absorption of oil or other lubricant of the "cylinder"): 1/2 pint.

Plastic film, transparent storm-window type (such as 4-mil Flex-O-Glass, by Warp Bros.): 3 sq. ft.

Grease-type lubricant, an all-purpose motor-breakin lithium grease such as "Siloo White Lube" or "Lubriplate No. 5 Space Age Lubricant": two approx. 10 oz. tubes.

Inner tube rubber, heavy truck or auto (cut from an old tube): 1 sq. ft.

FUNCTIONAL RELATIONS OF PARTS

Look at Figs. 2, 5, and 6. In Figs. 5 and 6, the lower, fixed part of the front end is pictured below the piston rod. The piston rod slides back and forth on the center of the fixed part of the front end (as indicated more clearly in Fig. 7), and in the notch in the removable part of the front end.



Fig. 5. Front End of the Durability Test Pump, showing the lower fixed part (below piston rod) and the upper removable part, that is held by 6 screws with flat washers. Felt weather-stripping makes the removable part airtight.



Fig. 6. Pump Built by Dale Huber, of Lake City, Florida in his home workshop, while guided only by the second draft of these repeatedly improved instructions. The removable part of the front end has been taken off, to insert the piston into the 12 x 12-in. "cylinder" under the PARTITION. The plastic flaps of this pump's flap valves are black: transparent plastic film is preferred.

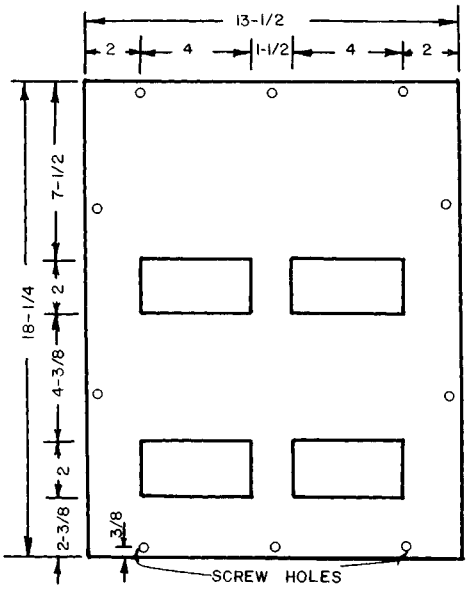


Fig. 8. Back End. Only the plywood is shown.

Note that a single plastic-film flap covers each pair of 2 x 4-in. valve holes, and that, as shown in Fig. 2 (that gives a side view of all six flaps), all flaps open **away** from the vertical center-plane of the pump.

In Fig. 5 the removable (upper) part of the front end is shown in place, secured by six round-head screws with flat washers. In Fig. 7 note the pair of 2 x 4-in. flap-valve holes above the piston rod.

In Fig. 6, the removable part of the front end has been removed, exposing the 26-in.-long, horizontal PARTITION that serves as the top of the 12 x 12-in. "cylinder", in which the piston can make a 24-in.-maximum-length stroke. Also see Figs. 2 and 7. Fig. 6 also shows the piston while it is being removed and one of the two rubber bumpers (made of inner tube rubber) on its piston rod.

The back end of the "box" is made of one piece of plywood, as shown in Fig. 8. The two plastic flaps of its exhaust valves each cover two 2 x 4-in. valve holes, that are positioned the same as the four valve holes in the front end.

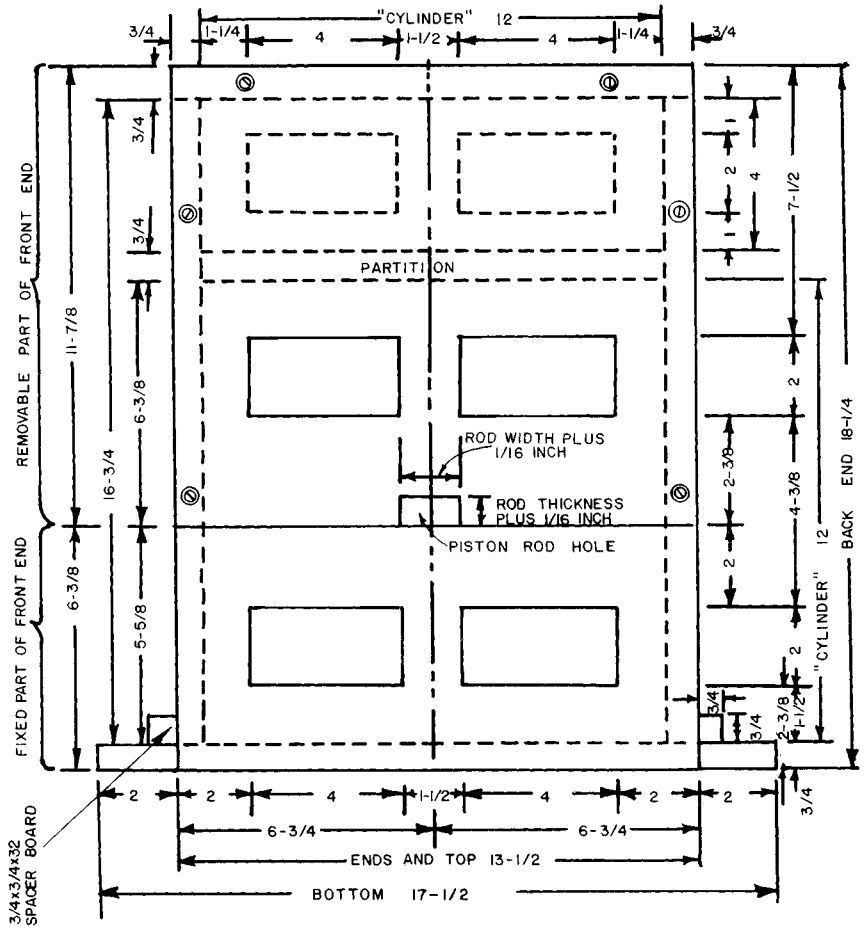


Fig. 7. Front End (Operator's End) of Plywood Double-Action Piston Pump. The two 4 x 12-in. valve frames are shown by dashed lines, as is the 12 x 26-in. PARTITION.

CUTTING OUT THE PLYWOOD PARTS

1. The four parts of the "cylinder" (its bottom, two sides, and the PARTITION; see Fig. 7) should be made with the wood grain of the plywood running in the same direction as the lengths of these parts. This reduces piston friction.

2. Outline on a sheet of **exterior** 3/4-in. plywood all of the plywood parts—except for the 12 x 12-in. piston and the two 12 x 12-in. construction forms, which are made of 3/8-in. **exterior** plywood. (If 3/8-in. plywood is not available, use 1/4-in.) Do not assume that the corners of a sheet of plywood are truly square. Also check the width of the sawcut of the saw to be used, and allow for this width when drawing adjacent outlines of parts on the plywood. Be sure to make all corners **square**.

3. If you do not have a table saw that saws accurately, or a heavy-duty saber saw, you will do well to pay a professional carpenter or cabinet maker to saw out the plywood parts—and also the piston rod if you are making it out of an oak board. A professional can accurately saw out all of the plywood parts and the 10 valve holes in about 2 hours, provided you have accurately outlined all saw lines.

4. Make the following plywood rectangles with tolerances of + or - 1/32 in.:

PARTITION, 12 x 26-in.
Two sides, each 16-3/4 x 32-in. (If your "3/4-in. plywood" actually is less than 11/16-in. thick, make the height of each of your sides 16-3/4-in. less the difference between 3/4-in. and the actual thickness of your plywood. See Fig. 7.)
Bottom, 17-1/2 x 32-in.
Top, 13-1/2 x 32-in.
Two valve frames, each 4 x 12-in.
Piston, 12 x 12-in. (of 3/8-in. plywood).
Two construction forms, each 12 x 12-in. (of 3/8-in. plywood).

5. Make the following plywood rectangles with tolerances of + or - 1/16 in.:

Back end, 13-1/2 x 17-1/4-in. (See Fig. 8.)
Removable (upper) part of front end, 13-1/2 x 10-7/8 in. (See Figs. 7 and 9.)
Fixed (lower) part of front end, 13-1/2 x 6-3/8-in. (See Figs. 7 and 10.)
The four parts of the air-intake duct: two each 6-1/2 x 6-in.; two each 6-1/2 x 7-1/2-in.
Two spacers (to be nailed to the bottom) each 3/4 x 3/4 x 32-in.

6. Saw out the 10 valve holes; a tolerance of + or - 1/8 in. is good enough. (See Figs. 7, 8, 9, and 10.)

7. Saw a square 6 x 6-in. hole in the center of the top, as shown in Fig. 2 — if you are going to install the homemade filter (described in separate instructions) directly on top of your pump. (To connect your pump to a round air-intake pipe, cut an appropriate round hole in the top.)

8. Sandpaper the finished sides of the PARTITION, the two sides, and the bottom, to reduce friction on the reciprocating piston. Use fine sandpaper.

9. Make and attach the 6 valve flaps, to complete the flap valves, that are the lowest resistance, quickest acting type tested.

a. Make a 3-3/4 x 5-3/4-in. cardboard TEMPLATE, using carbon paper to transfer lines of Fig. 11 to cardboard. (See Fig. 11 on page 7,

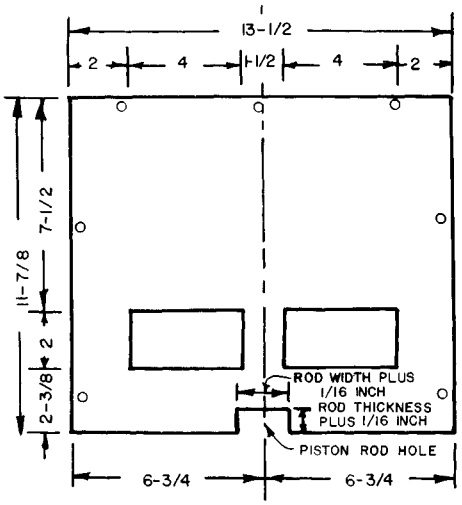


Fig. 9. Removable Part of Front End, Unfinished. Only the plywood is shown.

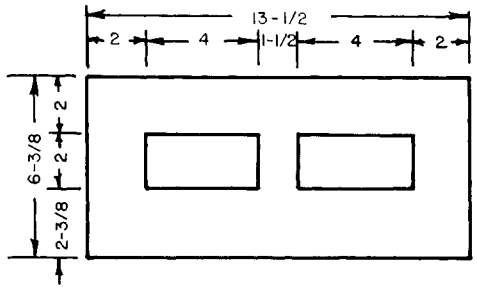


Fig. 10. Fixed Part of Front End, Unfinished. Only the plywood is shown.

and note that this TEMPLATE outlines the **right** half of the 3-3/4 x 11-1/2-in. plastic-film flap.) Also transfer the dashed tack-line and mark the ends of the 4 horizontal stop-string lines. Drill 8 small holes through the cardboard at the ends of the 4 stop-string lines, so that you can use a pencil to mark these points on plywood.

b. Use your TEMPLATE to mark around the 2 x 4-in. valve holes in plywood parts: (1) the positions of the ends of each hole's 8 stop-strings, (2) the **right** side-edge and the bottom-edge of each flap after it is attached, and (3) the tack-lines.

c. Drill a 1/16-in. diameter hole through the plywood at each point marked for an end of a stop-string.

d. With nylon kite string (or other nylon string about 1/16-in. in diameter, such as 50-lb-test nylon fishing line) and a big enough needle, string the "four" stop-strings across each 2 x 4-in. hole. (Use a string long enough to make "four" uncut stop-strings.) Start on the unfinished, back side of the plywood, on the opposite side from the future valve flap. To secure the starting end, wrap the string around a half-driven tack, and then drive it in. Keep pulling the string **tight** as you thread it through the holes and as you wrap its finishing end around a half-driven tack. Finally epoxy the string in all of the holes, on the back side of the plywood. (An equally strong nylon string can be made by twisting together 4 pieces of waxed nylon dental floss.)

(Stop-strings also can be positioned by using No. 3 upholstery tacks in place of the 1/16-in. diameter holes. Drive a tack partly in, wind the string around it while pulling the string tight, and drive the tack completely in, to hold the string securely. Finally, coat the tack heads and the adjacent plywood with a smooth covering of adhesive, to provide a smooth seat for the valve flap.)

e. Cut out 6 plastic flaps of transparent 4-mil plastic film (each 3-3/4 x 11-1/2 in.). The easiest way to accurately cut a flap of thin plastic film is to make a cardboard template 3-3/4 x 11-1/2-in., place it on the film, and cut around it with a very sharp knife.

f. In preparation for attaching a flap over each pair of 2 x 4-in. valve holes, cover the plywood **above** each pair of holes with masking tape, up to the straight "tack line" that you already have drawn 1/2 in. **above** each hole. Use your cardboard TEMPLATE. The masking tape will prevent the adhesive (that will be used to attach each valve flap) from being applied too near the 2 x 4-in. holes, where adhesive would keep a flap from opening fully.

g. Position each of the 6 flaps properly in its closed position, with its lower edge on the line that you already have used the TEMPLATE to draw 3/4 in. below each flap's pair of 2 x 4-in. holes. Position its **right** side-edge on the line already drawn 1 in. from the right side of the right hole of each pair of 2 x 4-in. holes. Then put masking tape over the lower edge of each flap and the adjacent plywood, to hold the flap temporarily in its closed position.

h. Gently fold down the upper part of each flap, so that the plywood above its pair of 2 x 4-in. holes is uncovered (except where you have placed the protective tape), and place small pieces of masking tape so as to hold each flap temporarily in this folded-down position.

i. Quickly apply a thin coat of all-purpose construction adhesive (such as Liquid Nails) to a 1/2-in.-wide plywood area above the protective masking tape that covers the plywood up to the "tack line" 1/2 in. above each pair of 2 x 4-in. valve holes. Then promptly detach the small pieces of masking tape holding the flap in its folded-down position, and turn the flap (the lower part of which is still being held in its proper closed position by masking tape) into the whole flap's closed position. Press the upper part firmly against the approximately 1/2-in.-wide coating of adhesive, to secure the valve in its proper closed position. Allow several hours for the adhesive to harden before removing the tape and using the valve.

j. Drive small tacks (No. 3; 3/8 in.) on the "tack line" (see TEMPLATE), to make sure the flap stays securely attached after long use. (Very small tacks are easily driven if held with tweezers or needle-nosed pliers.)

PUTTING THE PUMP "BOX" TOGETHER

1. The following procedure is the best tested construction method for persons who lack experience in putting parts together so that all corners are exactly square, or who do not have the big clamps and other glueing equipment used by cabinet makers. This procedure is best carried out by two persons working together.

2. On the finished side of the top, draw two parallel lines exactly 12 in. apart and parallel to the top's 32-in.-long edges. Each of these lines will be 3/4-in. from an edge. Also draw a line 6 in. from and parallel to each end of the top, to mark the positions of the two valve frames. See Fig. 2.

3. Build the pump's "box" **upside down;** start by placing its top on the floor, as indicated by Fig. 12.

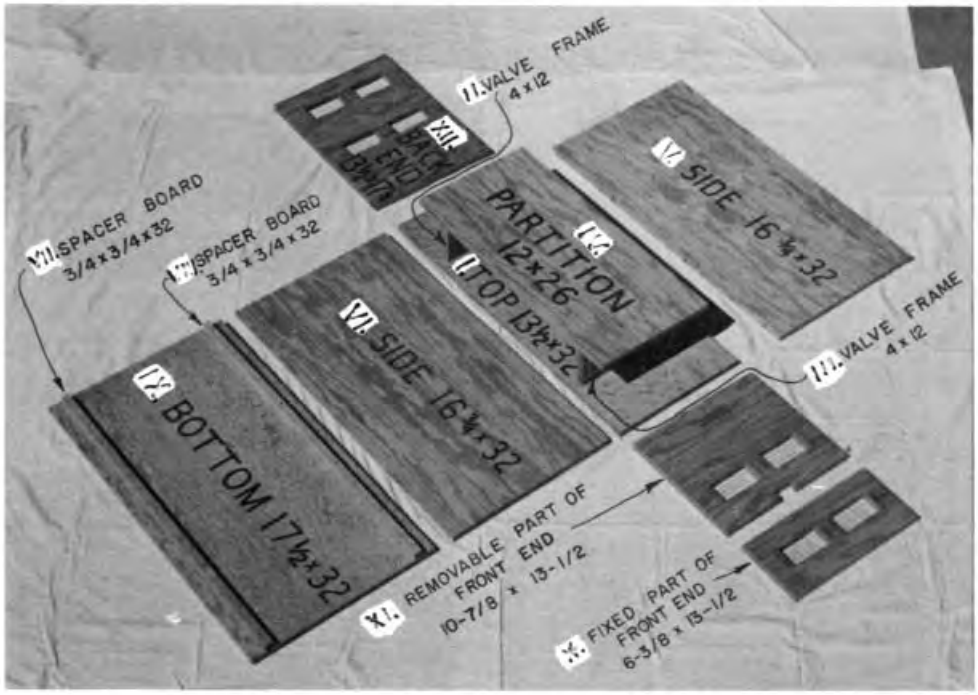


Fig. 12. Parts of the Pump "Box", with Dimensions in Inches. The Roman numbers give the best tested order for attaching these parts to each other.

4. Attach the two valve frames II and III to the top I with construction adhesive, positioning each of them 6 in. from an end of the top I. Make sure that each frame's flap valve is **upside down** and **facing away from the center** of the pump. Remove any adhesive that is on the top beyond the ends of the valve frames.

(When using construction adhesive to make this pump, it is best to apply a rather thin coat to only one of the two plywood surfaces to be joined. Then promptly rub one plywood part slightly back and forth against the other, while pressing them together—thus making sure that both surfaces are coated and in close contact. Wait until the adhesive sets and bonds adequately before attaching more parts.)

5. Draw two parallel lines on the unfinished side of the PARTITION, each 3 inches from one of its ends. Adhere the two 12-in.-long unattached edges of the valve frames to the PARTITION on these two lines, as illustrated by Figs. 2, 7 and 12. Allow time for the adhesive to set.

6. Before permanently attaching side V, position it vertically with a long edge resting on the top, and with a side-edge of the PARTITION and ends of the two valve frames I and II in contact with the finished side of side V. See Fig. 7. On the unfinished (outer) side of side V draw lines showing the positions of the PARTITION and of the two valve frames in contact with the finished side of side V.

7. Preparatory to attaching side V to the PARTITION and to the two valve frames, drill 4 slightly oversize screw holes (for your 2-in. roundhead screws) through side V. Drill these holes so that a screw will go into an end of each valve frame about 1 in. from its adhered edge, and the other 2 screws will go into the side-edge of the PARTITION, at points above the valve frames. Next, with side V temporarily in its final position, drill with a smaller diameter drill through the 4 holes in side V, into the PARTITION and into the two valve frames. Then with the 4 screws temporarily connect side V, the PARTITION, and the two valve frames, and, while checking with a carpenter's square the squareness of the angle between the PARTITION and side V, adjust the two pairs of screws to attain squareness. Remove side V.

8. Apply adhesive to the 3/4-in.-wide area along the long edge of the top, and if necessary a thicker coating of adhesive than normal to unattached edges of the PARTITION and of the two valve frames. Then promptly position side V, and by again screwing in and adjusting the 4 screws, make the angle between the PARTITION and side V **square.** Allow the adhesive to set.

9. Use short pieces of duct tape to temporarily attach the two 12 x 12-in. construction forms to the PARTITION and to side V. (Before using these forms, drive 4 small nails into each form, near its corners, to serve as handles for removing them from the completed "cylinder".) Attach a construction form near each end of the PARTITION.

10. Adhere the finished side of side VI to the top, to the unattached side-edge of the PARTITION, and to end-edges of the valve frames, while keeping side VI pressed against the two **square** construction forms. To keep side VI pressed against the construction forms until the adhesive sets, use small nails to temporarily nail two small boards horizontally across the ends of the sides, at each end of the "box".

11. On the finished side of the bottom IX, draw two parallel lines 13-1/2-in. apart, making each line 6-3/4-in. from the center line of the bottom, as shown in Fig. 7. Nail the two 3/4 x 3/4 x 32-in. spacer boards VII and VIII to the bottom, 13-1/2-in. apart.

12. To attach the bottom, first place it (with its finished side **down**) on the exposed long-edges of the sides. If you find that the bottom rests on the construction forms and is not in contact with the long-edges of the sides, in effect increase the heights of the sides by coating with adhesive both the edges of the sides and the 3/4-in.-wide area of the bottom to which the sides will be adhered. Then adhere the bottom onto the edges of the sides. Before the adhesive hardens, remove any that has been squeezed into the corner of the "cylinder".

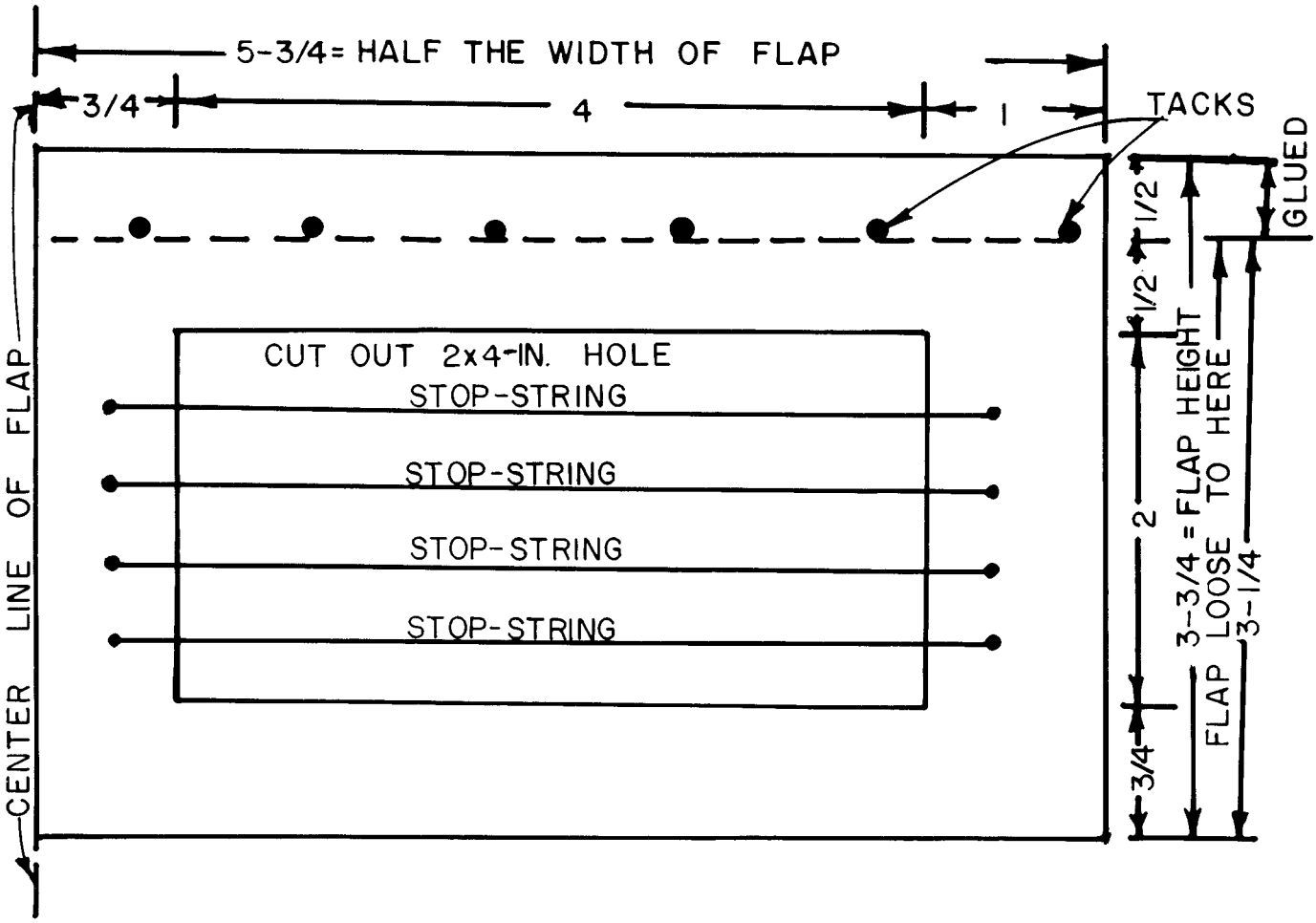


Fig. 11. TEMPLATE for Positioning the Stop-Strings of each of the 12 valve holes, and for attaching each of the 6 valve flaps.

TRACE THIS DRAWING. TO MAKE THE WORKING TEMPLATE, TRANSFER THE TRACING TO A PIECE OF CARDBOARD. CUT OUT THE 2 X 4-INCH HOLE IN THE CARDBOARD, AND MAKE SMALL HOLES SHOWING THE POSITIONS OF THE STOP-STRINGS AND TACKS.

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13. Permanently attach the fixed part of the front end X (see Fig. 7, 10 and 12) with adhesive and small nails to the sides and to the bottom. Be sure that its flap valve is **upside down** and is **facing away from the center** of the pump, and that a long edge of this part is level with the outer side of the bottom. Remove the construction forms.

14. Paint the interior of the "cylinder" with sealer—after removing all adhesive that may be in its corners.

15. After the sealer dries, sandpaper the interior of the "cylinder" with fine sandpaper, and paint it again with the final coat of sealer.

16. To attach the removable part of the front end XI, stand the "box" on its completely open end and drill slightly oversize screw holes (for your 2-in. screws) clear through the removable part of the front end, as indicated by Fig. 9. With the flap valve **facing outward**, temporarily attach this part with a few small nails to the end of the top and to ends of the two sides. Then with a smaller-diameter bit, drill the screw holes deep enough into the top and the sides so that the 7 screws will hold securely.

17. So that it will be unnecessary to tightly screw on the removable part of the front end in order to make its repeated temporary attachments airtight, tack felt weatherstripping (best 1/8-in. thick and 5/8-in. wide), or strips made of two thicknesses of flannel, to the contact edges of the top and the sides. No. 3 (3/8-in.) carpet tacks serve well. Then with a razor blade carefully cut the felt covering the screw holes in the edges, and remove these small pieces of covering felt.

18. Attach with screws the removable part of the front end.

19. To prevent damage to the front-end valve flaps when you stand the pump on its front end, epoxy a small piece of 3/8-in. plywood to the front end, near each of its four corners, as pictured in Figs. 3 and 5. Before standing the pump on its front end, use small pieces of masking tape to temporarily secure its valve flaps in their closed positions.

20. Attach the back end XII, using only screws. See Fig. 8. (For repairs, the back end may have to be removed.) To make the attachment of the back end airtight, coat its attachment "crack" only with rubber cement.

MAKING THE PISTON, THE PISTON ROD, AND ITS HANDLE

1. Have a sheetmetal shop cut three 3-ft.-long, 3-in.-wide strips of galvanized steel sheetmetal that is **no more than 0.016-in. thick** and no less than 0.012-in. thick. (Most galvanized steel valley flashing used by roofers and sold by many lumber yards is less than 0.016-in. thick; 30-gauge galvanized sheet metal sold by some sheetmetal shops is about 0.015-in. thick.) Steel sheetmetal thicker than about 0.016 in. is not springy enough and is unsatisfactory.

2. With a tolerance of + or - 1/32-in., cut from these strips two strips each 11-13/16-in. long, and two strips each 11-3/4-in. long. (These four strips first must be bent and then tacked to the four sides of the plywood piston; these piston-sealing strips serve rather like piston rings, by making close, sliding, low-friction contact with the sides of the plywood "cylinder". Steel strips resist wear and if properly lubricated make the pump serviceable for months of continuous use.)

3. Preparing the four sheetmetal sealing strips:

a. Since the strips to be tacked to the top and the bottom of the piston must be bent differently from the strips to be tacked to its two sides, mark "T or B" on each of the two strips that are 11-13/16 in. long, and mark "S" on each of the two strips that are 11-3/4 in. long.

b. On each of the two strips marked "T or B", draw an ink line along which to make the approximately 30 degree bend, and another line for the approximately 90 degree bend. (See the left half of Fig. 13 for the distances from the edges of these two "T or B" strips to their bends.) Also draw two ink lines along which to drive tacks, spaced as shown in the left half of Fig. 13.

Likewise draw four lines on each of the two strips marked "S", as specified in the right half of Fig. 13, noting that some of these lines are spaced differently than corresponding lines on the strips marked "T or B".

c. Using a small sharpened nail for a punch and placing one strip of sheetmetal at a time on a smooth board, punch 2 rows of tack holes in each strip. The tack holes should be about 1-1/2 in. apart.

d. From a nominal 1 x 2-in. **straight** board, make two boards each about 3/4 x 7/8 x 12-1/4 in., for use in bending the sealing strips.

e. Securely sandwich a "T or B" strip of sheetmetal between the two 12-1/4-in.-long boards placed exactly on top of each other, by tightening two "C" clamps on the ends of the two boards, so that the bending line 3/8-in. from one side of the strip is just visible along the straight edge of a board. Then hold the two clamped boards in a vise so that the 3/8-in.-wide part of the sheetmetal strip is uppermost and vertical.

f. Bend the exposed part of the strip about 30 degrees off the vertical, **away** from the side of the strip where the holes have been indented by the punch. To bend evenly, hammer gently and repeatedly on a 3/4 x 3/4 x 18-in. board held against the exposed 3/8-in.-wide part of the strip.

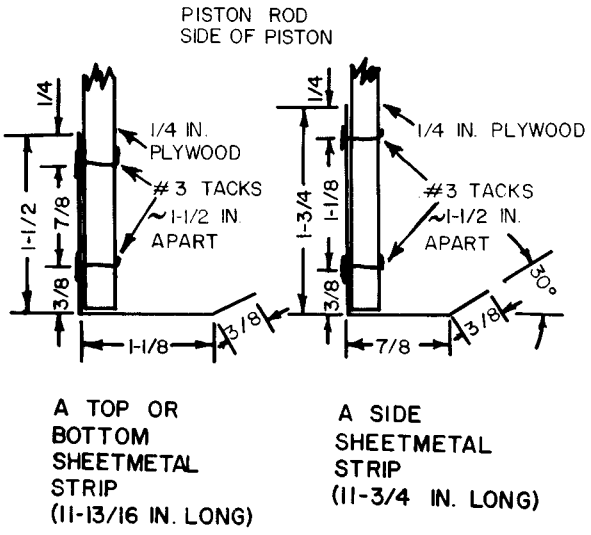


Fig. 13. Piston Sealing Strips, each made of a springy sheetmetal strip 3 in. wide.

g. With the sheetmetal strip held sandwiched between the two 12-1/4-in.-long boards by the two "C" clamps and the vise, so that the bending line for the almost 90-degree bend is barely visible, bend the exposed part of the strip 90 degrees, in the same direction that the 3/8-in.-wide part was bent. See Figs. 13 and 14.

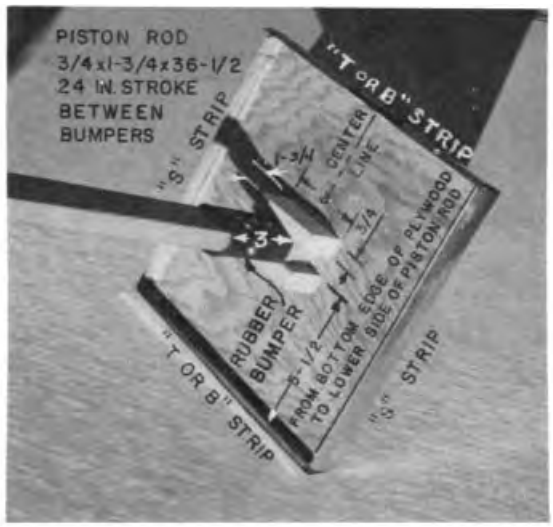


Fig. 14. Plywood Piston with Sheetmetal Sealing Strips Attached.

h. Bend the other "T or B" strip, and similarly bend each of the two "S" strips.

4. Attach the four sheetmetal sealing strips to the plywood piston with No. 6 tacks (1/2-in. long). Place on a solid metal surface the part of the plywood piston opposite the spot to which part of a strip is being tacked, so that when a tack is hammered in its point is **clinched** (bent over) on the far side of the 3/8-in.-thick plywood piston, by being hammered against the solid metal surface.

a. First tack a "T or B" sheetmetal strip to the top of the piston, and a "T or B" strip to its bottom.

b. Then tack the two "S" strips to its sides. The strips should fit together so as to make square corners. If adjacent ends of two strips do not fit neatly together, cut bit by bit a very little off the end(s) of a strip(s) so that the two adjacent ends fit together neatly at their corner.

c. To prevent air leakage between the ends of the sealing strips, put rubber cement in the four corner "cracks" between strips. (This was not done on the test pump's piston.)

5. For the piston rod, saw from a **straight, well-seasoned** oak board a 3/4 x 1-3/4 x 36-1/2-in. board. Sandpaper it smooth. (A piston rod made of well-seasoned oak is less likely to break if abused, but necessitates using screws, in place of nails and staples, for attachments. Piston rods made of nominal 1 x 2-in. fir boards were undamaged in the tests.)

6. To complete the piston rod:

a. For the handle, use 4 pieces of a nominal 1 x 2-in. board cut to the lengths shown in Fig. 15. Also see Fig. 16. Round all edges and corners, to minimize the chances of the operators' blistering their hands.

b. Paint the piston rod and its handle with sealer. When dry, sandpaper. Then apply a final coat of sealer.

c. Use adhesive, screws, and nails (or adhesive and nails if your piston rod is of soft wood) in making the handle illustrated by Fig. 15.

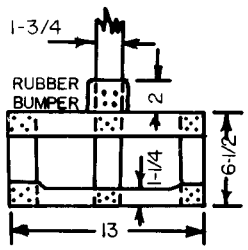


Fig. 15. Piston Rod Handle Made of 3/4 x 1-3/4-in. Boards.



Fig. 16. The Pump Handle of the Durability-Test Pump, showing how one man best holds it when two men are pumping.

d. To reduce friction on the piston rod and resultant enlargement of the piston-rod hole with long use, coat with epoxy all four sides of the piston-rod hole. See Figs. 7 and 16. Be sure that the piston rod slides snugly yet freely in its hole when the removable part of the front end is screwed in place.

e. From a piece of thick truck-tire inner-tube rubber, cut a 2-in.-wide strip 12-in. long. To make the 2-in.-wide rubber bumper (see Figs. 15 and 16), connect one end of this rubber strip to the center of a 3/4-in.-wide side of the piston rod. Do not place any screw or staple in the strip closer than 1 in. from the strip's forward edge, that may repeatedly bump into the front end. Wrap and attach the strip quite tightly around the piston rod next to the handle. (If you have only a piece of passenger-car inner-tube rubber, then to make a 2-in.-wide bumper use a 4-in.-wide strip of this thinner rubber folded double lengthwise.)

7. Attaching the piston rod to the piston:

a. On the back of the 12 x 12-in. plywood piston, mark lines to enable you to attach the piston rod as pictured in Fig. 14. Note that the **lower side** of the piston rod is exactly 5-1/2 in. above the lower edge of the plywood of the piston, and that the center line of the piston rod intersects the vertical center line of the plywood of the piston.

b. To the end of the piston rod (see Fig. 14) adhere and screw (or adhere and nail if your piston rod is not oak) two pieces of nominal 1 x 2-in. boards each 3 in. long. Each of these two small boards and the end of the piston rod are in contact with and securely connected to the plywood piston, and form a perfect "T" at the end of the piston rod.

c. Connect the piston rod to the piston, best with epoxy (or adhesive) and small screws. Make sure that: (1) the four piston sealing strips overlap the piston's plywood in the direction of the piston rod, (2) the 1-3/4-in.-wide sides of the piston rod are parallel to the top and bottom of the piston, and (3) the piston rod is perpendicular to the piston. See Figs. 2 and 14.

d. Make and attach to the piston rod a 3-in.-long rubber bumper, positioned close to the piston as shown in Fig. 2.

OPERATING THE PUMP

1. Check to see that the four sheetmetal strips on the four sides of the piston all make even contact with the walls of the "cylinder" when the piston is moved back and forth. If the piston does not slide back and forth quite easily even when not lubricated, carefully bend a strip or strips so that they press less against the "cylinder" walls. If while someone is shining a flashlight through a valve opening in the other end of the pump you observe that parts of a sheetmetal strip do not make close contact with a "cylinder" wall, gently bend outward that part of the strip.

2. Lubricate all four walls of the "cylinder", the sheetmetal strips that slide against the walls, and the piston rod. Use a very thin motor-breakin white lithium grease (not an ordinary bearing grease, that is too sticky). Or use a thin oil. The pump should be lubricated after no more than each 24 hours of use, and before being used again after days of disuse.

3. Install the pump at a height above the floor so that most of the persons who are going to pump can push and pull with their hands moving at about the same height that their elbows are when they are standing. See Fig. 3 for an example of a pump-supporting table raised to an efficient height for operators who are the height of the pumper pictured.

4. To save work and to minimize wear on the pump, usually operate it with a length of stroke a little shorter than the distance between its two rubber bumpers. To save energy especially when pumping air through a high resistance ventilation system, move the piston back and forth by using mostly your leg and body muscles.

PROLONGED STORAGE

Wipe off all grease and other lubricants if you do not plan to use this pump for months. All lubricants—especially those on wood—tend to become gummy with time.

Keep your supply of pump lubricants taped to your pump.

REQUEST

Suggestions for improving this pump and/or these instructions will be appreciated, and may contribute to improvements likely to save lives.

Cresson H. Kearny

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FILTER BOX AND FILTER

PURPOSES

The primary shelter ventilation requirement is to supply enough outdoor air to maintain endurable heat-humidity conditions.

To keep the concentration of respiratory carbon dioxide low enough for survival, very little fresh outdoor air is required. Even for an infant or an infirm person remaining in a crowded shelter for days, 3 cubic feet per minute (3 cfm) is adequate. For a healthy adult or child 1.5 cfm is enough. Too much carbon dioxide, not too little oxygen, is the initial cause of unendurable conditions in inadequately ventilated shelters in which the air does not get unendurably hot.

In contrast, up to 25 cfm of outdoor air per occupant may be needed to maintain endurable heat-humidity conditions inside a crowded shelter occupied for days during a heat wave in a hot, humid part of the U.S. Hence the need for a large-volume ventilating pump, best with a low-resistance filter.

If outdoor air flows into a shelter through a hood, gooseneck pipe, or other air-supply opening that causes all but tiny fallout particles to fall out before the air reaches shelter occupants, breathing this unfiltered air will not result in short-term radiation casualties. However, a very small fraction of the occupants of a shelter supplied with unfiltered air in an area of heavy fallout may contract cancer years later as a result of breathing shelter air containing tiny fallout particles, that a properly designed filter could have removed.

Air that has been in contact with fallout particles before being filtered is not radioactive.

The homemade filter illustrated below, if used with an efficient "suction" pump such as the Plywood Double-Action Piston Pump described separately, will remove practically all fallout particles likely to cause casualties even decades later. This filter also will remove most infective aerosols, the air-borne tiny particles used in biological warfare — an unlikely type of attack on the United States. It will not remove poisonous gasses, an even less likely danger to Americans if all-out war befalls us.

CONSTRUCTION

Filter Box

If 20 x 20-inch furnace filters are available, use plywood or boards to build the filter box shown in the illustration. To make permanent connections airtight, first use waterproof construction adhesive or glue, and then tape. (If only smaller filters are available, reduce the horizontal dimensions of the box accordingly, except for the top and bottom openings.) Check to be sure that your filters will fit snugly in the box of the size you plan to build.

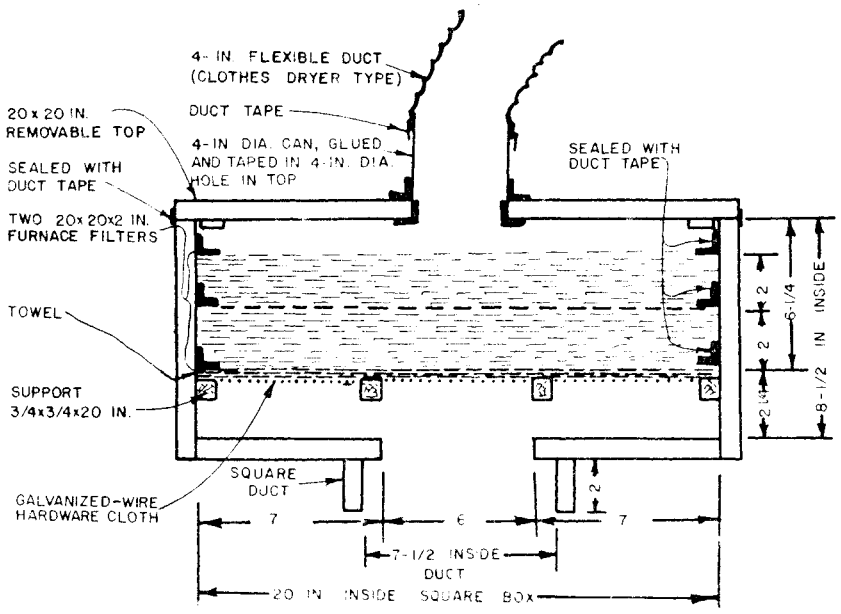
The square frame on the bottom of the filter box should fit snugly over the square air-intake duct on the top of your Plywood Double-Action Piston Pump. Tape the cracks to make the connection airtight and to permit easy removal of the filter box.

Make the illustrated 4 supports of the hardware cloth no thicker than 3/4 inch, thus providing enough space below the filter for low-resistance airflow. (Hardware cloth is a stiff, square-mesh, molten-dipped galvanized wire.)

Make the square top of the filter box so that it covers the upper edges of the box's sides and can be easily removed. Then cut in its center a round hole slightly smaller than 4 inches in diameter. File the hole's edges so that a 4-inch-diameter can (such as a coffee can with its top and bottom cut out) fits **snugly** in this hole. To connect the can securely and airtight, first use waterproof construction adhesive or epoxy, and then tape. (If construction adhesive or epoxy is not available, cut a 2-1/2-inch-diameter hole in the center of the bottom of the 4-inch-diameter can. Then make radial cuts spaced about one-half inch apart, out to the full diameter of the can. Bend these tabs outward 180 degrees, preparatory to tacking them with small tacks to the bottom of the filter box top. Tape airtight.)

So that the top of the filter box can be easily removed, tape it onto its box. A roll of duct tape should be kept with the filter box and pump at all times.

To connect the filter box to the shelter's air-intake pipe, the best widely available air duct is the inexpensive, 4-inch-diameter flexible duct used with clothes dryers.



Homemade Filter To Fit On Plywood Double-Action Piston Pump, and To Be Connected to a 4-Inch-Diameter Air-Intake Pipe.

Filter Materials

Furnace or air-conditioner dust filters, those made of oiled fiberglass fibers, will remove practically all but the very smallest fallout particles. Filters that are sold in box-like housings can easily be installed so that all the pumped air will pass through them, by taping them to the inner sides of the filter box. The illustration shows two plain mats of furnace filter material, each taped around its edges. (If commercial dust filters are not available, bath towel cloth will serve. However, in very dusty areas a cloth filter may become overloaded, thus seriously reducing the rate of airflow much sooner than if an oiled fiber filter is used as a prefilter.)

To filter out most of the tiny particles that may pass through one or more furnace filters, place two thicknesses of bath towel on top of the filter-support made of hardware cloth, and tape them around their edges to the box. See illustration.

Tests by U.S. Army specialists have shown that filtering air through two thicknesses of bath towel removes about 85 percent of even microscopic aerosols as small as 1 to 5 microns in diameter. (See "Emergency Respiratory Protection Against Radiological and Biological Aerosols", by H. G. Guyton et al., A.M.A. Archives of Industrial Health, Vol. 20, July through Dec. 1959.) This is the size of most infective aerosols used in biological warfare. In most of an area subjected to a biological attack, if 85 percent of this size-range of infective aerosols and practically all larger particles are removed, then most persons breathing this filtered air will not receive enough infective agents to infect and sicken them.

Persons who are especially desirous of protecting their shelter's occupants against biological warfare aerosols, but who can not afford or obtain expensive High Efficiency Particulate Air filters (HEPA filters), should consider using disposable pleated air filters that meet official ASHRAE standards. One 2-in. pleated air filter, measuring 19-1/2 x 19-1/2 in., will remove over 90 percent of particles in the 1.0-5.0 micron range, yet when clean its resistance to an airflow of 200 cfm is only about 0.2 in. water gauge (about 0.007 psi). Its cost is about twice that of a good ordinary furnace filter of the same size. However, it has approximately three times the life of a standard panel type filter before becoming overloaded. Disposable pleated air filters are available in larger cities.

USE

The illustrated homemade filter has such low resistance to airflow that, when up to about 200 cfm is being pumped through it by a Plywood Double-Action Piston Pump, the air volume is decreased by only about 10 percent, as compared to the volume pumped with no filter in the ventilation system. With a homemade Plywood Double-Action Piston Pump, up to approximately 200 cfm can be pumped through this filter even when the total difference in air pressure (caused by the ventilation pipes, a dirty filter, etc. that restrict airflow) is high, about 5 inches water gauge (0.18 psi).

Even if the United States suffers an all-out Soviet attack, only a small part of its area will be subjected to blast effects severe enough to injure the occupants of fallout shelters. (Fallout shelters are not designed to withstand blast, but especially typical earth-covered ones afford consequential blast protection.) In contrast, an installed filter, unless protected by an efficient blast valve, will be wrecked by a quite low-pressure blast wave that comes down its open air-intake pipe —even if the small part of the blast wave that would enter the shelter room through its open ventilation pipes is not nearly powerful enough to injure the shelter occupants. Thus unprotected installed filters will be wrecked in an area several times as large as the area in which occupants of fallout shelters will be injured by blast.

To be sure of having a filter in good condition, you can:

1. Make and keep in your shelter an extra complete filter, ready to replace your installed filter if it is damaged, or if it becomes overloaded with dust and its resistance to airflow becomes too high. Furthermore, if your filter is installed in your shelter room and becomes so radioactive with retained fallout particles that it is delivering a consequential radiation dose to shelter occupants, it is advantageous to be able to remove it, pitch it out, and install a replacement filter. (To be able to supply your shelter with unfiltered air in peacetime or after the end of consequential fallout danger, you should make and keep ready a duct with appropriate fittings to connect your pump directly to its air-intake pipe.)

2. If you have only one filter, do not install it before you need to filter the air supply. Connect your pump directly to the air-intake pipe, using an appropriate duct and fittings. Then before the attack and before the arrival of fallout (revealed by your fallout-monitoring instrument), keep your shelter well ventilated with unfiltered air. Whether or not your filter is installed, stop ventilating your shelter for a few hours while heavy fallout is being deposited outside — unless heat-humidity conditions become unbearable. If before shelter ventilation is stopped the shelter air does not contain an abnormally high concentration of carbon dioxide, then no outdoor air need be supplied for about 5 hours to prevent building up too high a concentration of respiratory carbon dioxide — provided there is about 70 cubic feet of shelter-room volume for each occupant.

AN ENCOURAGING REMINDER

Persons making preparations to improve their chances of surviving an all-out attack should realize that if the United States is hit with warheads the sizes of those in the 1987 Soviet intercontinental arsenal, the fallout particles of critical concern will be much larger than the extremely small particles (1 to 5 microns in diameter) which are not completely removed by this filter. Fallout particles this small produced by large nuclear explosions do not fall to the ground for many days to months after the nuclear explosions, by which time they have become much less radioactive. Essentially all of the larger particles can be removed merely by filtering the air through a few thicknesses of bath towel cloth.

Appendix D
Expedient Blast Shelters

INCREASING IMPORTANCE

The majority of urban and suburban Americans would need blast shelters to avoid death or injury if they did not evacuate before an all-out nuclear attack. As nuclear arsenals continue to grow, an increasing majority would need the protection of blast shelters. In an attack on militarily relevant targets, as much as 5% of the total area of the 48 states could be subjected to blast damage severe enough to destroy or damage homes — depending on the number of warheads assigned to each hard target, weapon reliability, etc. If blast shelters affording protection up to the 15-pounds-per-square-inch (15 psi) overpressure range were available to everybody and were occupied at the time of attack, the great majority of the occupants would survive all blast, fire, and radiation effects in the blast areas subjected to less than 15-psi blast effects.

Fifteen-psi blast shelters will survive as close as about 1.5 miles from ground zero of a 1-megaton surface burst, and about 2.3 miles from ground zero or a 1-megaton air burst. Except in high-density urban areas where the air supply openings and exits of shelters are all too likely to be covered with blast-hurled debris, the area in which people inside good earth-covered 15-psi blast shelters would be killed would be only about 1/6th as large as the area in which most people sheltered in typical American homes probably would die from blast and fire effects alone.

Blast tests have indicated that the Small-Pole Shelter (the most blast-resistant of the earth-covered expedient shelters described in Appendix A) should enable its occupants to survive up to the 50-psi overpressure range — if built with the blast-resistant and radiation-protective features described in following sections, and if located outside an urban area. Calculations show that this earth-covered expedient blast shelter also would give adequate protection at the 50-psi blast overpressure range against the intense initial nuclear radiation that is emitted from the fireball of a 1-megaton explosion. However, to make this shelter (see page 258) provide adequate protection against the even more intense initial nuclear radiation that would reach the 50-psi overpressure range from the fireball of a 500-kiloton or smaller explosion, it should have at least 6 feet of earth cover and additional cans of water should be kept ready to be placed in the horizontal parts of the entryways promptly after the shelter is occupied.

The life-saving potential of well designed, well built blast shelters is a demonstrated fact. Millions of Americans living in high-risk areas would be able to build expedient blast shelters within only a few days—provided they were given field-tested instructions, had made some preparations before the crisis arose, had a few days of recognized warning, and during the crisis were motivated by the President. The following information is given in the hope of encouraging more Americans to make preparations for blast protection. Also, it may serve to increase the number who realize the need for *permanent* blast shelters in high-risk blast areas.

Some informed citizens—particularly those who live near large cities or in their outer suburbs—may choose to build earth-covered expedient blast shelters in their backyards, rather than to evacuate. Going into a strange area and trying to build or find good shelter and other essentials of life would entail risks that many people might hesitate to take, particularly if they live outside the probable areas of severe blast damage. For such citizens, the best decision might be to stay at home, build earth-covered expedient blast shelters, supply them with the essentials for long occupancy, and remain with their possessions.

The following descriptions of the characteristics and components of expedient blast shelters should enable many readers to use locally available materials to provide at least 15-psi blast protection. Pre-crisis preparations are essential, as well as the ability to work very hard for two to four days. (Field-tested instructions are not yet available; to date only workers who were supervised have built expedient blast shelters.[5])

PRACTICALITY OF EXPEDIENT BLAST SHELTERS

At Hiroshima and Nagasaki, simple wood-framed shelters with about 3 feet of earth over wooden roofs were undamaged by blast effects in areas where substantial buildings were demolished.[4]

Figure D.1 shows a Hiroshima shelter that people with hand tools could build in a day, if poles or timber were available. This shelter withstood blast and fire at an overpressure range of about 65 psi. Its narrow room and a 3-foot-thick earth cover brought about effective earth arching; this kept its yielding wooden frame from being broken.



Fig. D.1. A small, earth-covered backyard shelter with a crude wooden frame—undamaged, although only 300 yards from ground zero at Hiroshima.

Although the shelter itself was undamaged, its occupants would have been fatally injured because the shelter had no blast door. The combined effect of blast waves, excessive pressure, blast wind, and burns from extremely hot dust blown into the shelter (the popcorning effect) and from the heated air would have killed the occupants. For people to survive in areas of severe blast, their shelters must have strong blast doors.

In nuclear weapons tests in the Nevada desert, box-like shelters built of lumber and covered with sandy earth were structurally undamaged by 10- to 15-psi blast effects. However, none had blast doors, so occupants of these open shelters would have been injured by blast effects and burned as a result of the popcorning effect. Furthermore, blast winds blew away much of the dry, sandy earth mounded over the shelters for shielding; this resulted in inadequate protection against fallout radiation.

Twelve different types of expedient shelters were blast-tested by Oak Ridge National Laboratory during three of Defense Nuclear Agency's blast tests.[5] Two of these tests each involved the detonation of a million pounds or more of conventional explosive; air-blast effects equivalent to those from a 1-kiloton nuclear surface burst were produced by these chemical explosions.

Several of these shelters had expedient blast doors which were closed during the tests. Figure D.2 shows the undamaged interior of the best expedient blast shelter tested prior to 1978, an improved version of the Small-Pole Shelter described in Appendix A. Its two heavy plywood blast doors excluded practically all blast effects; the pressure inside rose only to 1.5 psi—an overpressure not nearly high enough to break eardrums. The only damage was to the expedient shelter-ventilating pump (a KAP) in the stoop-in entryway. Two men worked about 5 minutes to replace the 4 flap-valves that were blown loose.



Fig. D.2. Undamaged interior of a Small-Pole Shelter after blast testing at the 53-psi overpressure range. Large buildings would have been completely demolished.

When blast-tested at 5-psi overpressure, not even the weakest covered-trench shelters with unsupported earth walls (described in Appendix A) were damaged structurally. However, if the covering

earth were sandy and dry and if it were exposed to the blast winds of a megaton explosion at the 5-psi overpressure range, so much earth would be blown away that the shelter would give insufficient protection against fallout radiation. Much of the dry, shielding earth mounded over some of the above-ground shelters was, in fact, removed by the blast winds of these relatively small test explosions, even at the lower overpressure ranges at which homes would be wrecked. In contrast, in blast tests where the steeply mounded earth was damp, little blast-wind erosion resulted. (The reader should remember that even if shelters without blast doors are undamaged, the occupants are likely to suffer injuries.)

CONSTRUCTION PRINCIPLES

Millions of Americans—if given good instructions, strong motivation, and several days to work—should be able to build blast shelters with materials found in many rural areas and suburban neighborhoods. During a crisis, yard trees could be cut down for poles and sticks, and a garage or part of a house could be torn down for lumber. Many average citizens could build expedient blast shelters if they learn to:

- **Utilize earth arching by making a yielding shelter.** The remarkable protection that earth arching gives to those parts of a shelter designed to use it is illustrated by Fig. D.3.

This picture shows the unbroken roof of a 4-foot-wide Pole-Covered Trench Shelter that was



Fig. D.3. Effective earth arching in the earth covering of this 4-ft-wide Pole-Covered Trench Shelter prevented a single pole from being broken by blast forces that exerted a downward force of 53 psi (over $3\frac{1}{2}$ tons per square foot) on the overlying earth.

built in rock-like soil and blast tested where the blast pressure outside was 53 psi. Its strong blast doors prevented the blast wave from entering. Without the protection of earth arching that developed in the 5 feet of earth cover over the yielding roof poles, the poles would have been broken like straws. In contrast, the ground shock and earth pressure produced by 1-kiloton blast effects almost completely collapsed the unsupported, rock-like earth walls.



Fig. D.4. Post-blast interior of an Above-ground, Door-Covered Shelter that survived 1-kiloton blast effects at the 5.8-psi overpressure range. The shelter walls were made of bedsheets containing earth, as described in Appendix A.

Figure D.4 also indicates the effectiveness of earth arching. This photo shows the roof of a small, earth-covered fallout shelter, as it appeared after surviving blast effects severe enough to demolish most homes. The roof was made of light, hollow-core, interior doors and looks as though it had been completely broken. In fact, only the lower sheets of $\frac{1}{8}$-inch-thick veneer of the hollow-core interior doors were broken. (These breaks were caused by a faulty construction procedure—a front-end loader had dumped several tons of earth onto the uncovered doors.) The upper $\frac{1}{8}$-inch-thick sheets of veneer were bowed downward, unbroken, until an earth arch formed in the 2-foot-thick earth covering and prevented the thin sheets from being broken. Earth arching also prevented this roof from being smashed in by blast overpressure that exerted a pressure of 5.8 psi (835 pounds per square foot) on the surface of the earth mounded over this open shelter. (See Appendix A for details of construction.)

- **Make shelters with the minimum practical ceiling height and width.** Most of the narrow

covered-trench shelters used by tens of thousands of Londoners during the World War II blitz were built with only $4^{1}/_{2}$-foot ceilings, to maximize blast protection and minimize high water-table problems. These shelters were found to be among the safest for protection against nearby explosions. The Chinese also have a good understanding of this design principle and skillfully utilize the protection provided by earth arching. A Chinese civil defense handbook states: "... the height and width of tunnel shelters should be kept to the minimum required to accommodate the sheltering requirements," and "The thicker the protective layer of earth, the greater the ability to resist blast waves."[21]

- **Shore earth walls to prevent their caving in as a result of ground shock and earth pressure.** Most unshored (that is, unsupported) earth walls are partially collapsed by ground shock at much lower blast overpressures than those at which a flexible roof protected by earth arching is damaged. Figure D.5 is a picture of a seated dummy taken by a high-speed movie camera mounted inside an unshored, Pole-Covered Trench Shelter of the Russian type tested at the 20-psi range. (A second dummy was obscured by blast-torn curtains made of blankets.) The shelter had an open stairway entryway, positioned at right angles to the stand-up-height trench and facing away from the targeted "city" so as to minimize the entry of blast waves and blast wind.



Fig. D.5. A dummy in an unshored Pole-Covered Trench Shelter as it is struck by collapsing rock-like earth walls. The photo also shows the shelter's blanket-curtains as they are torn and blown into the shelter by the 180-mph blast wind. (Immediately after this photo was taken, the dummies were hit by the airborne blast wave and blast wind. Outside, the blast wind peaked at about 490 mph.)

Figure D.6 is a post-blast view of the essentially undamaged earth-covered roof poles and the disastrously collapsed, unshored shelter walls of the Russian shelter tested at 20 psi.[21] Russian civil defense books state that unshored fallout shelters do not survive closer to the blast than the 7-psi overpressure range. This limitation was confirmed by an identical shelter tested at 7 psi; parts of its unshored walls were quite badly collapsed by the ground shock from an explosion producing merely 1-kiloton blast effects.



Fig. D.6. Dummies after ground shock from 1-kiloton blast effects at the 20-psi range had collapsed the rock-like walls of a hardened desert soil called caliche. The dummies' steel "bones" and "joints" prevented them from being knocked down and buried. The fallen caliche all around them kept them from being blown over by the air blast wave and 180-mph blast wind that followed.

Unsupported earth walls should be sloped as much as practical. The length and strength of available roofing material should be considered and, in order to attain effective earth arching, the thickness of the earth cover should be **at least** half as great as the distance between the edges of the trench.

The stability of the earth determines the proper method for shoring the walls of a trench shelter.

Methods for shoring both loose, unstable earth and firm, stable earth are described below:

*In loose, unstable earth such as sand, the walls of all underground shelters must be shored. First, an oversized trench must be dug with gently sloping sides. Next, the shoring is built, often as a freestanding, roofless structure. Then earth must be

backfilled around the shoring to a level a few inches higher than the uppermost parts of the shoring, as in Fig. D.7. Finally, the roof poles or planks must be placed so that they are supported only by the backfilled earth. Blast tests have indicated that a Pole-Covered Trench Shelter thus proportioned and lightly shored should protect its occupants against disastrous collapse of its walls at overpressure ranges up to 15 psi.

* **In firm, stable earth,** it is best first to dig a trench a few inches wider than 7 feet (the length of the roof poles) and 1 foot deep. Next, dig the part to be shored, down the center of this shallow trench, using the dimensions given for the shoring in Fig. D.7. The trench walls should be sloped and smoothed quite accurately, so that the shoring can be tightened against the earth. If the shoring does not press tightly against the trench walls, large wedges of earth may be jarred loose, hit the shoring, and cause it to collapse.

A different, comparatively simple way to tighten shoring is indicated by Fig. D.8. This sketch shows a 4-pole frame designed to be installed every $2\frac{1}{2}$ feet along a trench in stable earth and to be tightened against trench-wall shoring with the same dimensions as those shown in Fig. D.7. Note that the two horizontal brace poles have shallow "V" notches

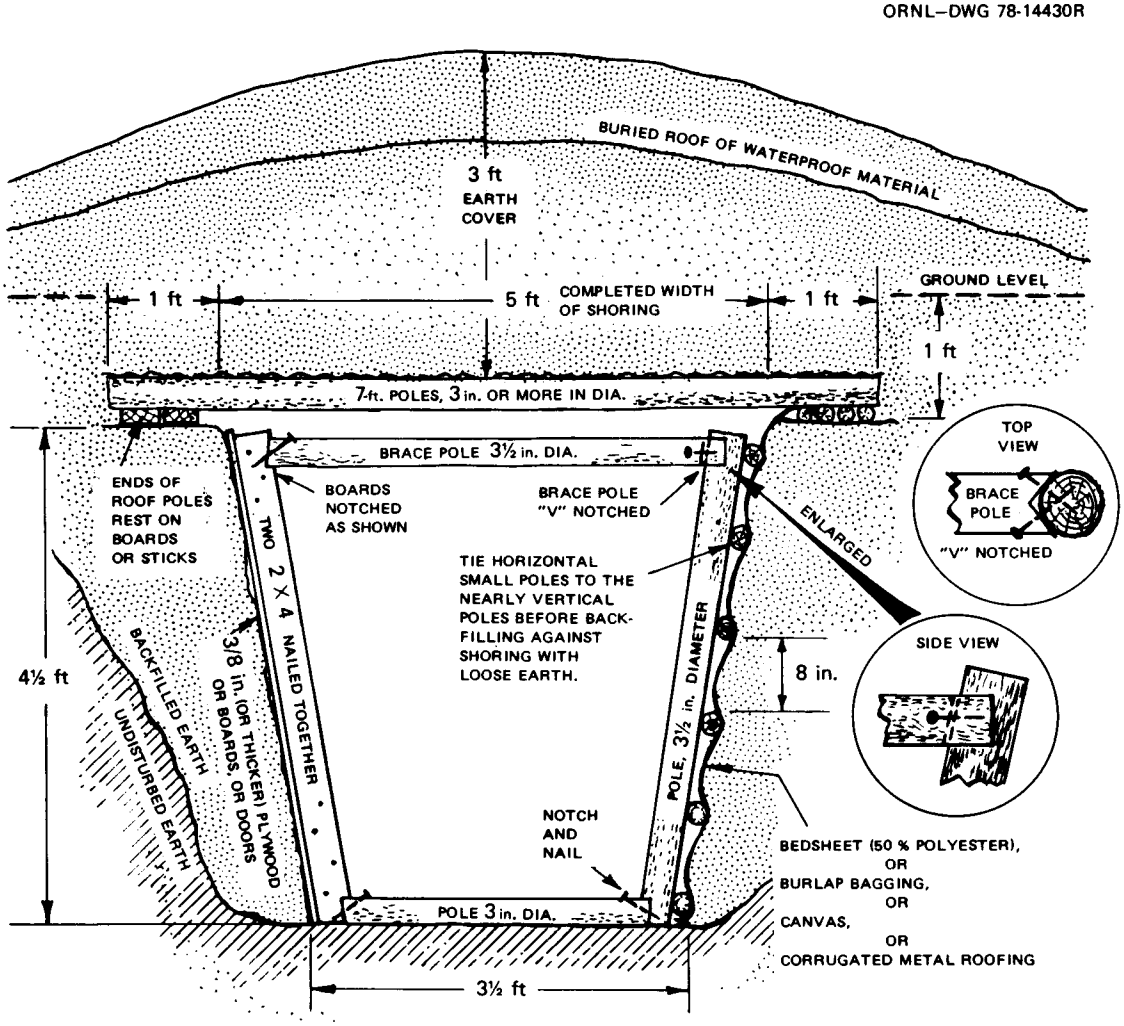


Fig. D.7. An illustration of several ways to shore a trench in unstable earth, using various materials. A 4-piece frame (consisting of 4 poles, or 4 boards, installed as shown above) should be installed every $2\frac{1}{2}$ feet along the length of the trench, including the horizontal parts of the entryways. All parts of the shoring should be at least 2 inches below the roof poles, so that the downward forces on the roof will press only on the earth.

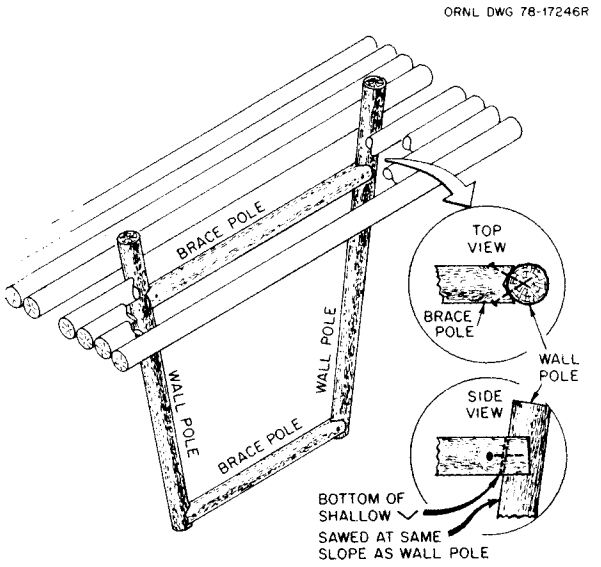


Fig. D.8. A 4-pole frame designed so that it can be tightened against the shoring materials that must press firmly against the walls of a trench dug in stable earth. (In this sketch, the middle sections of three poles have been removed, so that the upper brace pole may be seen more clearly.)

sawed in both ends. If these brace poles are driven downward when positioned as shown, the two wall poles are forced outward against the shoring materials placed between them and the earth walls. An upper brace pole should be cut to the length needed to make it approximately the same height as the roof poles on each side of it (no higher) after the shoring is tightened. Finally, each "V"-notched end should be nailed to its wall pole.

Light, yielding poles can serve simultaneously both to roof and to shore a shelter. A good example is the Chinese "Man" Shelter illustrated in Fig. D.9, requiring comparatively few poles to build.[21] This shelter is too cramped for long occupancy, and its unshored, lower earth walls can be squeezed in by blast pressure. Therefore, it is not recommended if sufficient materials are available for building a well-shored, covered-trench shelter. It is described here primarily to help the reader understand the construction of similarly designed entryways, outlined later in this appendix. The room and the horizontal entryway of the model tested were made of $6^1/_2$-foot poles averaging only 3 inches in diameter. It had two vertical, triangular entries of ORNL design. Each was protected by an expedient triangular blast door made of poles. In Fig. D.9, note the two small horizontal poles at the top of the triangle, one tied inside and the other tied outside the triangle, to hold the wall poles together. Before covering this shelter with earth, a 6-inch-thick covering of small limbs was placed horizontally across the approximately 3-inch-wide spaces between the $6^1/_2$-foot wall poles; the limbs were then covered with bedsheets.

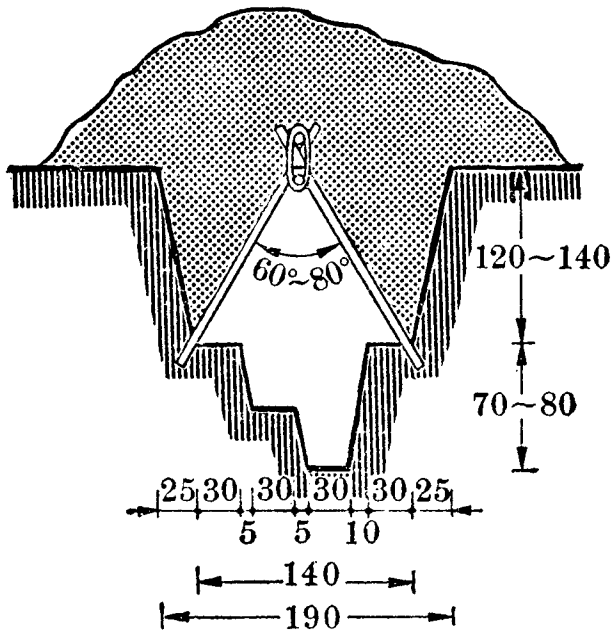


图 3-107 人字形骨架避弹所

Fig. D.9. Chinese "Man" Shelter tested at 20 psi, and undamaged because the thin poles yielded and were protected by earth arching. This drawing was taken from a Chinese civil defense manual. The dimensions are in centimeters.

When blast-tested in loose, unstable soil, the unsupported earth walls of the trench below the wall poles were squeezed in. The 12-inch width of the foot trench was reduced to as little as 4 inches by the short-duration forces produced by 0.2-kiloton blast effects at 50 psi. The much longer duration forces of a megaton explosion would be far more damaging to the shelter at lower overpressure ranges, due to destabilizing and squeezing-in unshored earth at depths many feet below ground level.

Calculations based on blast-test findings indicate that the unsupported earth walls of a shelter are likely to fail if the aboveground maximum overpressure is greater than 5 to 7 psi and this overpressure is caused by an explosion that is a megaton or more.

(Most homes would be severely damaged by the 3-psi blast effects from a 1-megaton or larger weapon. This damage would result one mile closer to ground zero of a 1-megaton surface burst than the distance at which the unshored earth walls of some shelters would be collapsed. For a 20-megaton surface burst, the corresponding reduction in distance would be about 2.7 miles.)

- **Build sufficiently long and strong entryways.** Blast shelters need longer horizontal entryways, taller vertical entryways, and thicker earth cover than do most fallout shelters; these are needed primarily for increased protection against high levels of initial nuclear radiation. The entryways of the Small-Pole Shelter described in Appendix A.3 (with the improvements for increased blast protection outlined in the following section of this appendix) afford protection against both blast and radiation up to the 50-psi overpressure range. However, these entryways require straight poles 14 feet long; these may be difficult to find or transport.

In contrast, both the horizontal and the vertical parts of the triangular entry pictured in Figs. D.10, D.11, and D.12 require only small-diameter, short poles. Triangular entries of this type were undamaged by 1-kiloton blast effects at the 20-psi overpressure range[5] and by 0.2-kiloton blast effects at 50 psi. This type of entry and its blast door (also triangular and made of short poles) can be used with a wide variety of expedient blast shelters and should withstand megaton blast effects at 25 psi. Therefore, their construction is described in considerable detail.

* **The horizontal part of a triangular entry:** If the Chinese "Man" Shelter shown in Fig. D.9 is made without excavating the unshored lower trench that forms its earth seats, it will serve as a horizontal, shored crawlway-entry affording blast protection up to at least the 25-psi overpressure range. Two horizontal entries, one at each end of the shelter, should be provided. Each entry should be 10 feet long. This length is needed to reduce the amount of initial nuclear radiation reaching the blast shelter room while assuring adequate through-ventilation. The outer part of such a horizontal entry is pictured in the background of Fig. D.10.

* **The vertical part of a triangular entry:** The *lower section* of the vertical part is made in a similar manner to the horizontal shelter shown in Fig. D.9. Figure D.10 shows $4\frac{1}{2}$-foot horizontal poles (1) forming a "V", with one end of each pole laid on top of the adjacent lower pole. The other ends of these poles (1) are pressed against the two pairs of vertical posts (2). (After this photo was taken, the tops of these two pairs of vertical posts were sawed off as

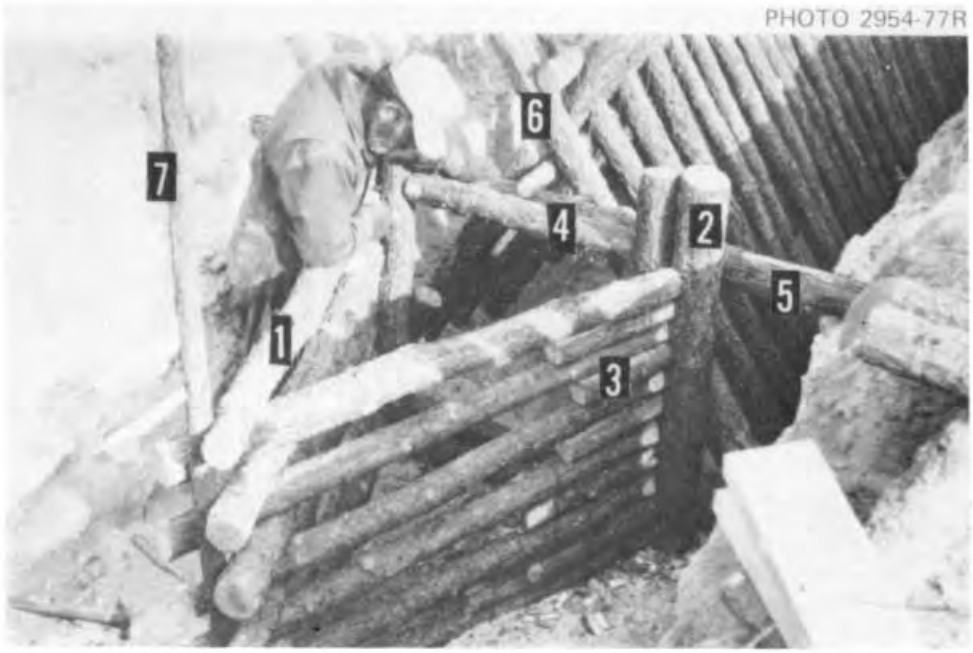


Fig. D.10. Uncompleted lower section of a vertical triangular entry.

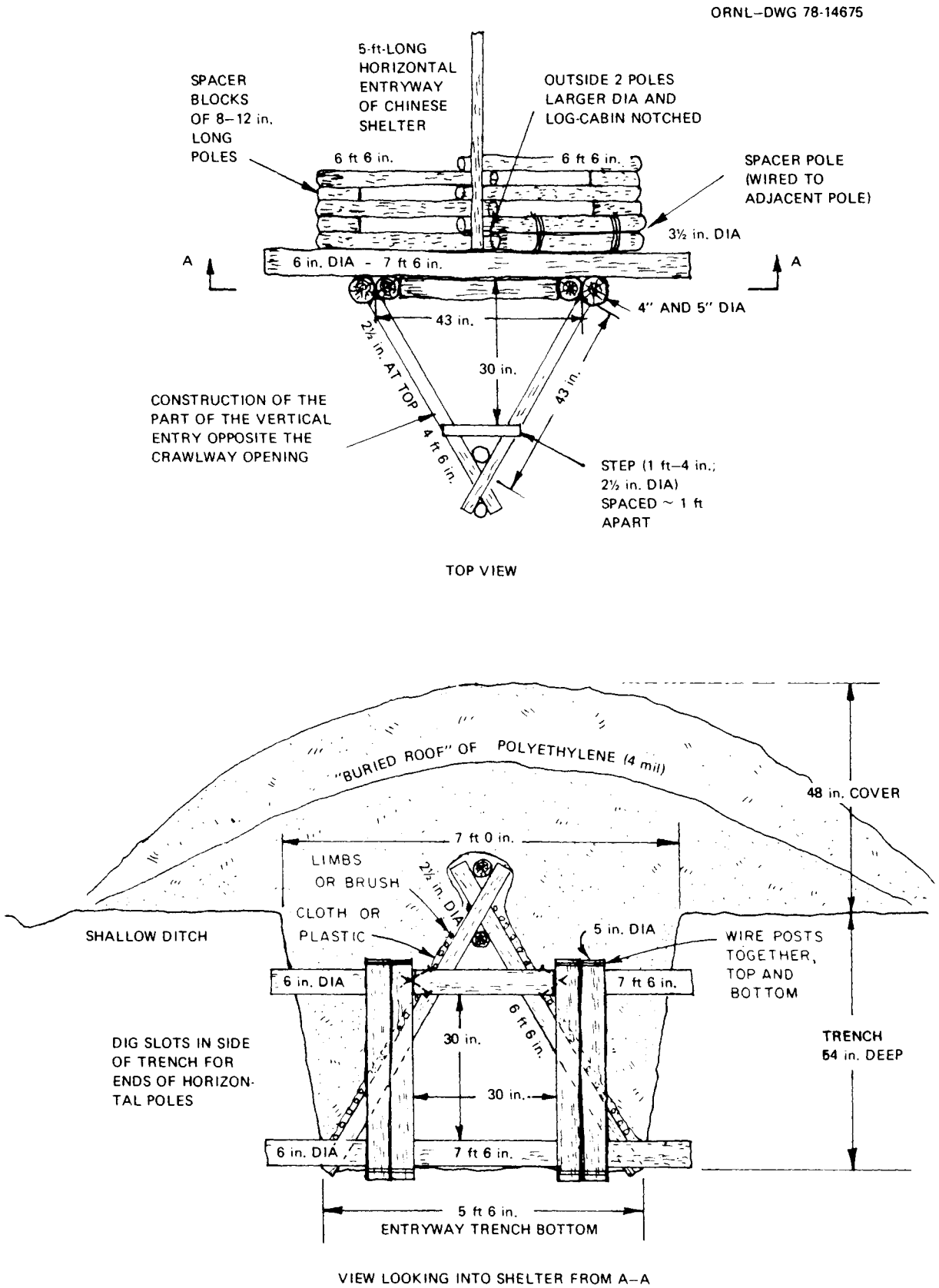


Fig. D.11. Lower part of a vertical triangular entry, showing its connection to the horizontal part of the shelter entry.

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Fig. D.12. Completed frame of Chinese "Man" Shelter showing its two ORNL-designed entryways (one at each end) and triangular blast doors made of poles. Before covering the triangular vertical entries with earth, tree branches were placed vertically over the sides; the branches then were covered with bedsheets. Horizontal branches, also covered with bedsheets, were laid over the rest of the shelter frame. After being covered with earth, this shelter was subjected to 1-kiloton blast effects. Multiple earth arching over and around this yielding structure prevented both the small poles and the bedsheets from being damaged at 20 psi.

shown in Fig. D.11.) The $4^1/_2$-foot horizontal poles (1) were kept level by the short spacer-poles (3) that were wired or nailed in place.

Each pair of vertical posts (2) was securely wired together at top and bottom. The two pairs were held apart at top and bottom by two horizontal brace-poles toenailed in place to frame the rectangular 30-×30-inch crawlway "doorway" between the vertical entry and the horizontal entry. Only the upper pole (4) of these two 30-inch-long horizontal brace-poles is shown.

The two pairs of vertical posts (2) were positioned so that they pressed against two $7^1/_2$-foot horizontal poles (5); only the uppermost is shown. These in turn pressed against the outermost two poles (6) of the horizontal entry and against the earth in two slot-trenches dug in the sidewalls of the excavation. These two $7^1/_2$-foot poles (5) should be at least 6 inches in diameter.

Additional details of the lower section of this vertical triangular entry are given in Fig. D.11. If horizontal poles considerably larger in diameter than those illustrated are used, fewer poles are required and strength is increased. However, the space inside the entry is decreased unless the larger-diameter horizontal poles that form the "V" are made longer than $4^1/_2$ feet.

As shown on the left in Fig. D.10, a small, vertical pole (7) was placed in the small "V" between the outer ends of the horizontal poles that form the lower section of the vertical entry. After this photo was taken, a second small, vertical pole was positioned in the adjacent large "V", inside the entry. These two poles (7) were then tightly wired together so as to make a strong, somewhat yielding, outer-corner connection of the horizontal poles (1)—in the same way that the tops of the side-wall poles of the Chinese "Man" Shelter are bound together.

The **upper section** of the vertical part of this entry (the section above the tops of the two pairs of vertical posts shown in Fig. D.10 and Fig. D.11) is made by overlapping the ends of its nearly horizontal poles (Fig. D.12). These poles [marked with a (1) in Fig. D.10] were each 4 feet 6 inches long and varied uniformly in diameter from about $2^1/_2$ inches just above the two pairs of wired-together posts, to 4-inch diameters just below the triangular door frame of poles. The triangular-shaped blast door was hinged

to and closed against this door frame. The hinges were strips cut from worn auto tires, to be described shortly.

The upper section is formed by laying poles in a triangular pattern, ends crossing at the angles, with large ends and small ends placed so that the poles are as nearly horizontal as is practical. Each of its three corners is held together by strong wires that tightly bind an outside and an inside small vertical pole, in the same manner as the top of the Chinese "Man" Shelter (shown in Fig. D.9) is secured. (Instead of No. 9 soft steel wire, rope or twisted strips of strong fabric could be used.)

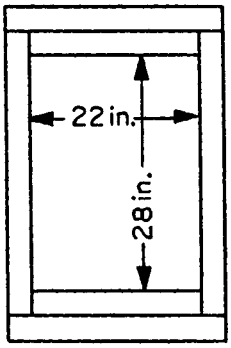
Before starting to install the upper section of a vertical triangular entry, the three outermost of the six small vertical poles that will hold the three corners together should be connected temporarily with three small horizontal poles. Connect them at the height of the door frame planned for the triangular blast door, and space them so as to be the same size as this door frame.

Next, all the horizontal poles should be laid out on the ground in the order of their increasing diameters. The triangular entry then should be started with the smallest poles at the base, with increasingly large-diameter poles used toward the top—so that the three pairs of small vertical poles will press securely against all the horizontal side poles of the entry.

To prevent the negative overpressure ("suction") phase of the blast from yanking out and carrying away the blast door and the upper part of the vertical entry to which it is hinged, the uppermost 4 or 5 horizontal poles of each of the three sides of the vertical entry should be wired or tied securely together. Rope or strips of strong cloth can be used if strong wire is not available.

Before placing earth around this lightly constructed blast-protective entry, the vertical walls must be covered to a thickness of about 6 inches with a yielding, crushable covering of limbs, brush, or innerspring mattresses. Limbs or brush should be placed in three layers, with the innermost layer at right angles to the underlying poles. The yielding thickness then is covered with strong cloth, such as 50% dacron bedsheets, or two thicknesses of 4-mil polyethylene film. This outermost covering keeps loose earth or sand from filling spaces inside the yielding layer or running into the entry. Thus protected, this vertical entry should be undamaged by 25-psi blast effects of megaton weapons.

A vertical blast-protective entry can also be made like a strong box, using 2-inch-thick boards. Such entries afford blast protection up to 50 psi if made as small as shown here and protected with yielding materials such as a 6-inch-thick layer of brush covered with strong cloth.



- **Install blast doors** to keep out airborne blast waves, blast wind, overpressure, blast-borne debris, burning-hot dust and air, and fallout.

A fast-rising overpressure of as little as 5 psi will break some people's eardrums. At overpressures of 15 to 20 psi, 50% of the people who are exposed will have their eardrums broken. However, persons near a shelter wall may have their eardrums broken by somewhat less than half of these unreflected overpressures. (Any wall may reflect blast waves and greatly increase overpressures near it.) Broken eardrums are not serious in normal times, but after a nuclear attack this injury is likely to be far more dangerous to persons in crowded shelters without effective medical treatment. Lung damage, that can result from overpressures as low as 10 to 12 psi, would also be more serious under post-attack conditions.

A blast door must withstand blast waves and overpressure. Not only must the door itself be sufficiently strong to withstand forces at least as great as those which the shelter will survive, but in addition the door frame and the entranceway walls must be equally as strong. The expedient blast door pictured in Fig. D.13 was made of rough boards, each a full 2 inches thick. It had a continuous row of hinges made of 18-inch-long strips cut from the treads of worn car tires.

The strips were nailed to the vertical poles on one side of the vertical entry. These and other details of construction are shown in Fig. D.14. Although the two center boards were badly cracked by the shock wave and overpressure at the 17-psi range, the door



Fig. D.13. Blast door surrounded by 4 blast-protector logs that were notched and nailed together. The wet, mounded soil had been compacted by the blast but not blown away.

pictured in Fig. D.13 afforded good protection against all blast effects from a surface explosion of a million pounds of TNT. In Fig. D.14, note the *essential,* strong tie-down attachment of the wires at the bottom of the vertical entry, to prevent the blast door from being yanked open by the negative pressure ("suction") that follows the overpressure.

Blast doors must be protected against reflected pressures from blast waves that could strike an edge of an unprotected door and tear it off its hinges. Note the blast-protector logs installed around the door pictured in Fig. D.14. When the door was closed, the tops of these four logs were about 2 inches higher than the door, thus protecting its edges on all sides.

The closed door must be prevented from rebounding like a spring and opening a fraction of a second after being bowed down by overpressure, or from being opened and perhaps torn off its hinges by the partial vacuum ("suction") that follows the overpressure phase. Figure D.14 gives the details of such a hold-down system for a blast door. Note that near the bottom of the vertical entry the 6 strong wires must encircle a horizontal pole that is flattened on one side and nailed to the vertical wall poles with at least a dozen 6-inch (60-penny) nails. Blast tests up to the 53-psi overpressure range have proved that this hold-down system works.[5]

Figure D.15 shows a blast door made of 5 thicknesses of $^{3}/_{4}$-inch exterior plywood, well glued and nailed together with $4^{1}/_{2}$-in. nails at 4-in. spacings. This door was protected by 4 blast-protector logs, each 8 feet long and about 8 inches in diameter. The logs were notched, nailed together, and surrounded with earth. For protection against ignition by the thermal pulse from an explosion, exposed wood and rubber should be coated with thick whitewash (slaked lime) or mud, or covered with aluminum foil.

An equally strong blast door and the door base upon which it closes can be made of poles. If poles are fresh-cut, they are easy to work with ax and saw. Figure D.16 shows the best blast-tested design. This door also had a continuous row of hinges made from worn auto tire treads. The pole to which the hinges were attached was 7 inches in diameter after peeling and had been flattened on its top and outer sides. The two other poles of the equal-sided triangle were 8 inches in diameter and had been flattened with an ax on the bottom, top, and inner sides. The three poles were each 55 inches long. They were notched and spiked together with 60-penny nails so that the door would close snugly on its similarly constructed base made of three stout poles. Other poles, at least 7 inches in diameter before being hewn so that they would fit together snugly, were nailed side-by-side on top of the three outer poles.

Many Americans have axes and would be able to cut poles, but not many know how to use an ax to hew flat, square sides on a pole or log. This easily acquired skill is illustrated by Fig. D.17. The worker should first fasten the pole down by nailing two small poles to it and to other logs on the ground. Figure D.17 shows a pole thus secured. When hewing a flat side, the worker stands with his legs spread far apart, and repeatedly moves his feet so that he can look almost straight down at where his ax head strikes. First, vertical cuts with a *sharp* ax are made about 3 or 4 inches apart and at angles of about 45° to the surface of the pole, for the length of the pole. These multiple cuts should be made almost as deep as is needed to produce a flat side of the desired width. Then the worker, again beginning at the starting end, should cut off long strips, producing a flat side.

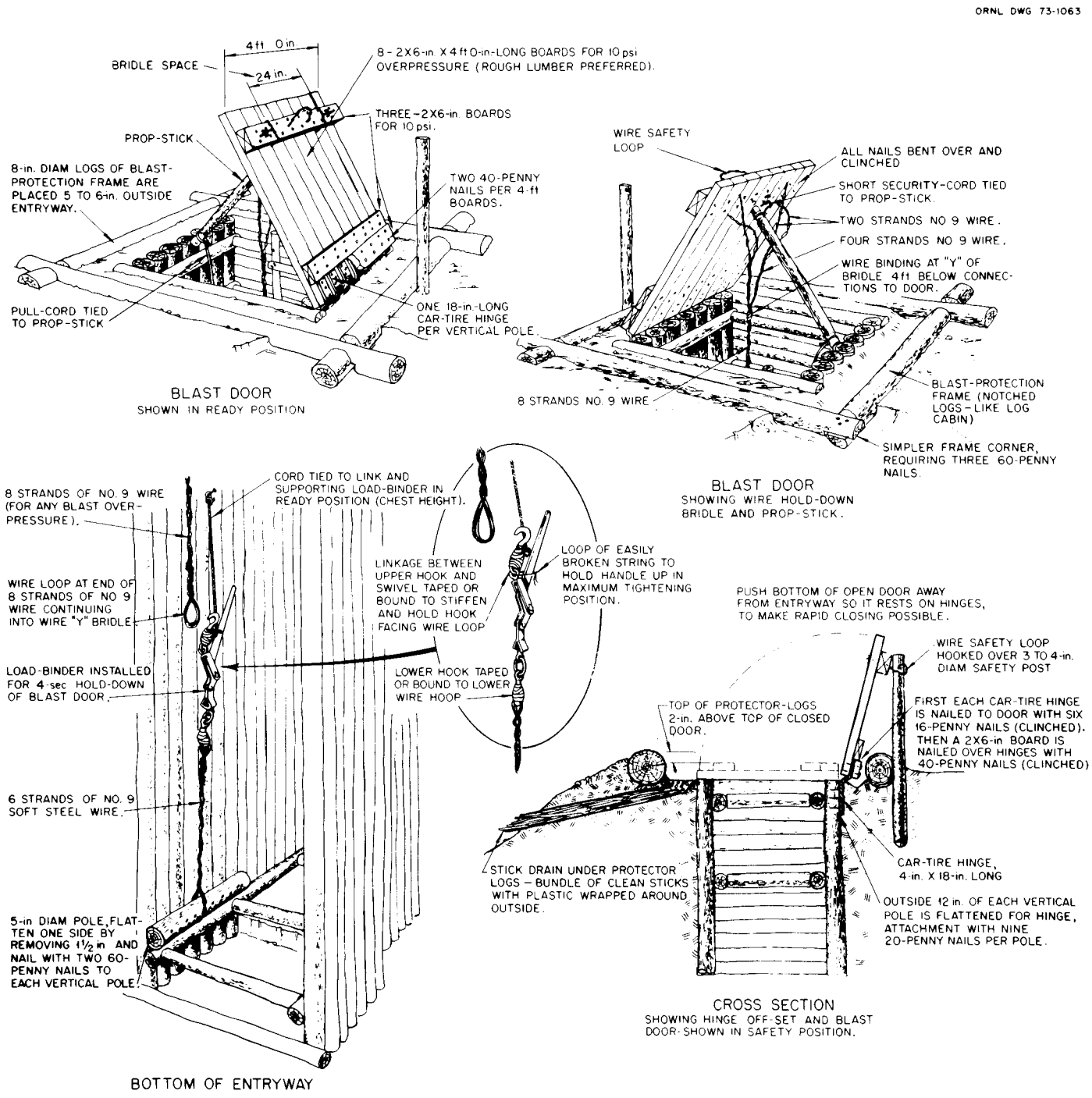


Fig. D.14. Expedient blast door that can be closed and secured in 4 seconds. Four seconds would be too little time if the shelter is at the 15-psi overpressure range from a 550-kiloton or smaller warhead — typical of the 1987 Soviet ICBM arsenal. (See the last paragraph on page 255.) However, this door closure is still the best blast-tested expedient means to secure a closed blast door.



Fig. D.15. Tire-strip hinges nailed to an expedient, 4-inch-thick blast door made of plywood, designed to withstand 50-psi blast effects of very large weapons and undamaged by blast at the 53-psi range.



Fig. D.16. Blast-tested triangular blast door made of hand-hewn pine poles, notched and nailed together. This door closed on a triangular pole base that is concealed in this photo by two of the three blast-protector logs that also withstood 53-psi blast effects.



Fig. D.17. Hewing flat sides on a pole with a sharp ax.

To hew a second flat side at right angles to the first side, rotate the pole 90°, secure it again, and repeat—as pictured in Fig. D.17.

- **Provide blast closures for an adequate ventilation system.** The following two expedient closure systems permit adequate volumes of ventilating air to be pumped through a shelter:

1. **Install two blast doors,** one on each end of the shelter, designed to be left open until the extremely bright light from a large blast is seen. Figure D.14 shows a door held open by a prop-stick that can be yanked away by the attached pull-cord. While propped open, one blast door serves as an extremely low-resistance air-intake opening, and the other serves as an air-exhaust opening. A large KAP can pump air at the rate of several thousand cubic feet per minute through such open doors.

When an attack is expected, each pull-cord should be held by a shelter occupant who stays ready at all times to yank out the prop-stick as soon as he sees the light of an explosion. After the door has fallen closed, the loop at the end of its wire bridle is close to the upper hook of the load-binder and at the same height (Fig. D.14). The person who closes the door should quickly hook the upper hook of the load-binder into the wire loop and pull down on the handle of the load-binder. The door will then be tightly shut. (Sources during an emergency would be the millions of load-binders owned by truckers and farmers.)

At distances from a large explosion where blast wave and overpressure effects are not destructive enough to smash most good expedient blast shelters, there is enough time between the instant the light of the explosion is seen and the arrival of its blast wave for an alert person to shut and securely fasten a well-designed blast door. The smaller the explosion and the greater the overpressure range, the shorter the warning time. Thus at the 15-psi overpressure range from a 1-megaton surface burst (1.5 miles), the blast wave arrives about 2.8 seconds after the light; whereas at the 10-psi overpressure range from a 1-megaton surface burst (1.9 miles), the blast wave arrives about 4.5 seconds after the light. For a 20-megaton surface burst, the warning time at the 15-psi range is about 8 seconds, and at the 30-psi overpressure range, about 4 seconds. Experiments have shown that even people who react quite slowly can close and secure this door within 4 seconds after seeing a spotlight shine on the door without warning.

2. **Build a vertical air shaft next to the outermost side of each vertical entry, with an Overlapping-Flaps Blast Valve** (see Fig. D.18) connecting each entry to its air shaft, as shown in Fig. D.19. These air shafts and blast valves permit forced ventilation to be maintained when the two blast doors are closed. Figure D.18 illustrates the construction of a fast-closing expedient blast valve, a design that was undamaged by the 65-psi shock wave and other effects produced by the explosion of a million pounds of TNT. When blast-tested in a shock-tube at 100-psi, the flaps were undamaged; they closed in 6/1000 of a second (0.006 sec.). This is as fast as the best factory-made blast valves close.

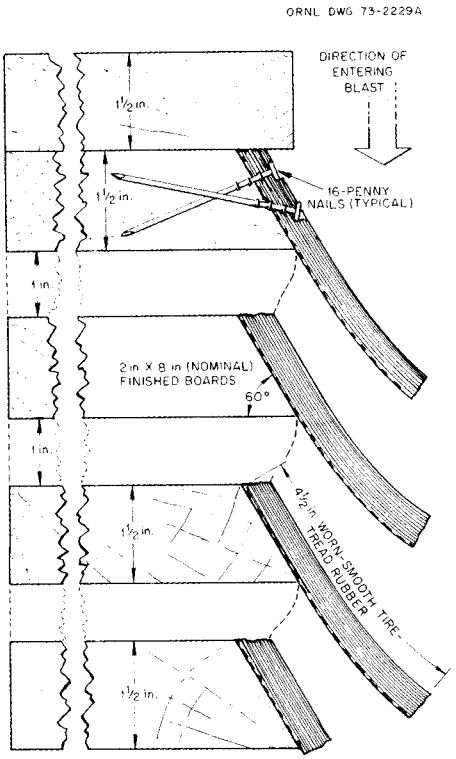


Fig. D.18. Overlapping-Flaps Blast Valve, made of boards, plywood, and strips cut from the treads of worn car tires.

To withstand 50 psi, the load-bearing "2-inch" boards (actually 1½ inches thick) of the valve should be at least 6 inches wide, if the 1-in.-high air openings are each made 12 in. wide, measured between two vertical poles of a shelter entry. See Fig. D.19, that gives the dimensions of a valve that has been blast tested.[5] Note that there are 5 inches of solid wood at each end of each 1-in.-high air opening. If there are 5 such air openings to a valve, a properly installed KAP (Appendix B) can pump air at about 125 cubic feet

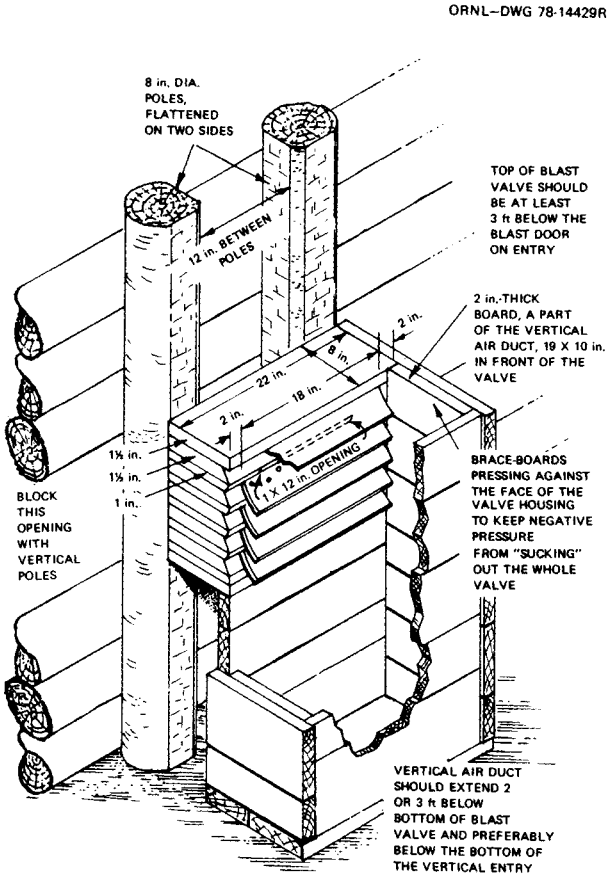


Fig. D.19. Installation of a 50-psi Overlapping-Flaps Blast Valve in such a way that it will not be blown into a shelter by the blast overpressure, nor pulled out by the following negative pressure ("suction") phase.

per minute (125 cfm) through a shelter equipped with such valves. This ventilation rate is ample for at least 40 people in cold weather. Except in hot and humid weather, a constant air supply of about 10 cfm per shelter occupant is enough to maintain tolerable conditions during continuous shelter occupancy for many days.

If a factory-made blower capable of pumping more than 100 cfm is available, use it. Such a hand-operated blower can pump against much higher air flow resistances than a KAP can. It can pump its full-rated volume of outdoor air through a shelter equipped with two Overlapping-Flaps Blast Valves, one at each end of the shelter and each with only 2 air openings—providing a total of 24 square inches of openings per valve. Equally or more effective is a homemakeable Plywood Double-Action Piston Pump, made and operated as described in Appendix E.

Remember that a pressure of 7200 pounds pushes against each square foot of the exposed face of

a blast valve when it is subjected to a 50-psi blast overpressure. Also keep in mind that the "suction" that follows can exert an outwardly directed force of up to 700 pounds per square foot on the valve face and can yank it out of position unless it is securely installed. Figure D.19 shows how to securely install a blast valve. (Merely nailing a blast valve in its opening will not enable it to withstand severe blast forces.)

Note in Figure D.19 that an opening is shown between the back edge of the uppermost board of the Overlapping-Flaps Blast Valve and the adjacent horizontal pole of the vertical entry. Both this opening and the similar opening next to the lowermost board of the Blast Valve should be closed off with a stout board, to prevent blast from going through these openings and on into a vertical entry and the shelter room.

The top of an air shaft should be a few inches higher than the earth piled around it, as are the tops of the vertical entries of the Small-Pole Shelter illustrated in Figure A.3.1 on page 174. To minimize the amount of rain that may fall into an air shaft, a shed-like, open-sided miniature roof should be placed over it, a few inches above its top. The roof can be lightly constructed, since it will be blown away by a severe blast.

- **Minimize aboveground construction and the mounding of shielding earth.** At high overpressure ranges, the shock wave and the blast-wind drag can wreck an aboveground shelter entry. For example, the 5-ft-high earth mound over a shelter built with its pole roof at ground level was moved enough by 1-kiloton air-blast effects at the 53-psi overpressure range to break one of the poles of a blast-door frame. The forces of a 1-megaton explosion at the same overpressure range would have operated 10 times as long, and probably would have smashed the vertical entryways of this shelter. Whenever practical, a blast shelter should be built far enough belowground so that the top of its shielding earth cover is at ground level. Avoiding aboveground construction and earth mounds also greatly reduces the chances of damage from blast-hurled, heavy debris, such as tree trunks and pieces of buildings.

Dry earth, steeply mounded over a shelter which is subjected to blast winds from a big explosion, will be mostly blown away. However, blast-wind "scouring" of **wet** earth is negligible. The blast winds from a 1-kiloton explosion at the 31-psi overpressure range scoured away 17 inches of **dry,** sandy soil mounded at a slope of 32°.

If it is impractical to build a blast shelter with its roof belowground, good protection can be attained by mounding even dry earth at slopes not steeper than 10°.

- **Provide adequate shielding against initial nuclear radiation.** Good expedient blast shelters require a greater thickness of earth cover than is needed on good fallout shelters, for these reasons:

  * Blast shelters should also protect against initial nuclear radiation emitted by the fireball. This radiation is reduced by half when it penetrates about 5 inches of packed earth (as compared to a halving-thickness of only about 3½ inches of earth against radiation from fallout).
  * The initial radiation, in some areas where good blast shelters will survive, can be much greater than the fallout radiation is likely to be.
  * Initial nuclear radiation that comes through entryways is more difficult to attenuate (reduce) than fallout radiation. Therefore, longer entryways or additional right-angle turns must be provided.

For these reasons, good blast shelters should be covered with at least 4 ft of well-packed, average-weight earth, or 5 ft of unpacked or light earth. (A 3-ft thickness gives excellent protection against radiation from fallout.)

A 50-PSI SMALL-POLE SHELTER

This expedient blast shelter is described in detail to enable the reader to build this model. The details will help him better understand the design principles of other expedient blast shelters that are capable of preventing injuries from blast effects severe enough to destroy all ordinary buildings and kill the occupants. Blast tests and calculations have indicated that the Small-Pole Shelter described and illustrated in Appendix A.3 will afford protection against all weapon effects at overpressure ranges up to 50 psi that are produced by an explosion of 1 megaton, or *larger,* provided the shelter is:

- Made with horizontal entryways each with ceilings no higher than 7 ft, 2 in., no wider than 3 ft, and each at least 10 ft long—to lessen the radiation coming through the entries (see Fig. D.20). Lower and narrower entryways would give better protection but would increase the time required for entry.

- Constructed with a floor of poles that are 4 in. or more in diameter, laid side-by-side, with the wall poles resting on the floor poles. The ground shock and earth pressures at a depth of 10 ft or more resulting from an overpressure on the surface of more than about 35 psi, if caused by a large explosion, may destabilize and squeeze earth upward into the shelter through an unprotected earth floor. The Small-Pole Shelter described in Appendix A.3 has an earth floor.

- Installed in an excavation about 13 feet deep, with the shelter's vertical entrances appropriately increased in height so that the blast doors are only about one foot above the original ground level.

To prevent possibly life-endangering cave-in of the 13-foot-deep trench that was dug for the blast testing of this model shelter, the trench walls were sloped about 45 degrees. The shelter was built as a braced, free-standing structure, and then covered. During a crisis it would be impractical to safely excavate a deep trench with steeply sloping walls and then safely build a shelter in it. A 13-foot-deep trench is usually too deep to dig by hand—especially since to dig it with safely sloping walls requires the removal of a large amount of earth.

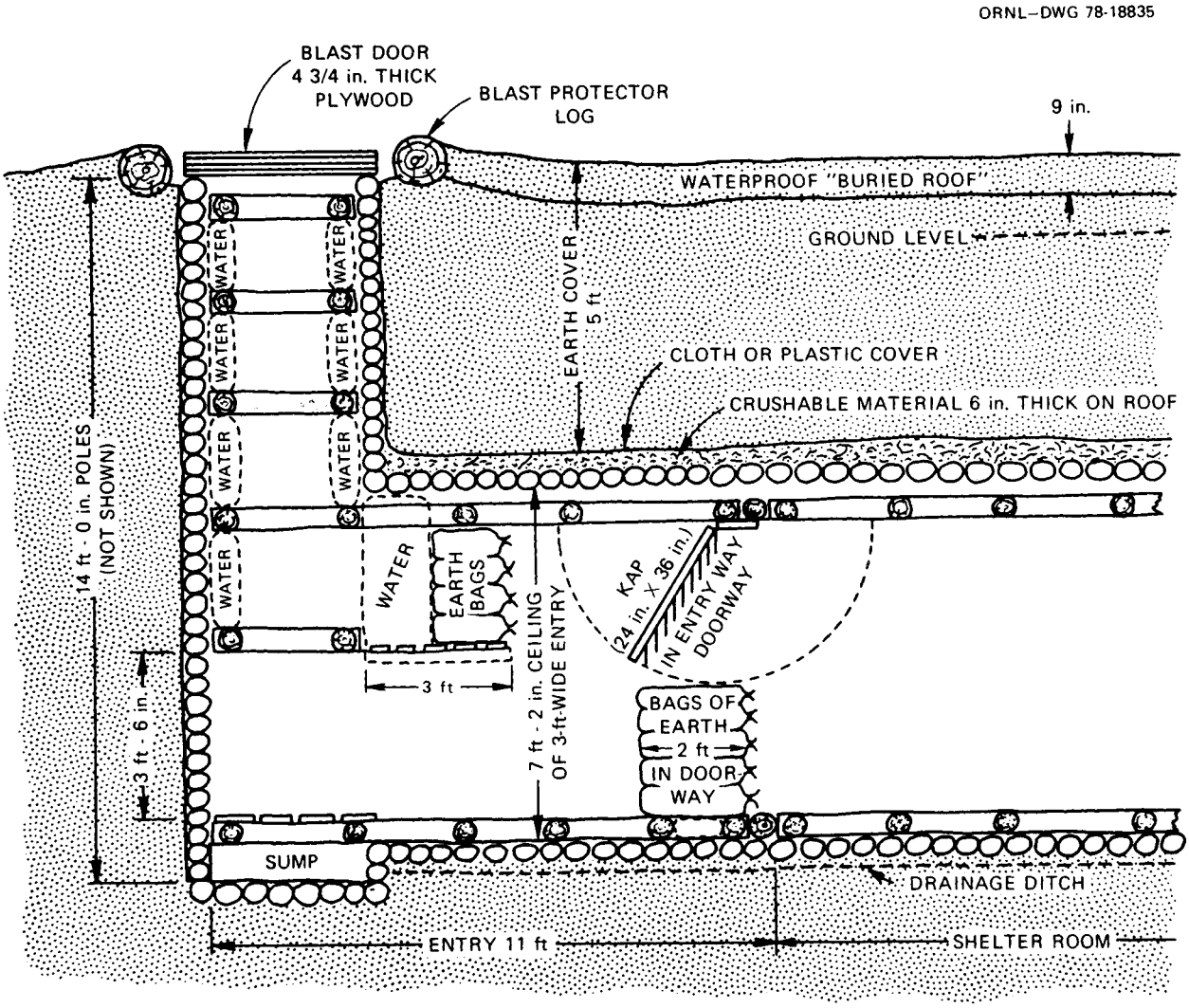


Fig. D.20. Entryway of Small-Pole Blast Shelter shielded against initial nuclear radiation. This sketch is a simplified vertical section through the centerline of one end of the shelter.

- Made with 4 rectangular horizontal braces in each vertical entry, in addition to the ends of the two long, ladder-like braces. The detailed drawings in Appendix A show such braces. The lowest rectangular brace should be positioned $3\frac{1}{2}$ feet above the flooring at the bottom of the vertical entry (see Fig. D.20).

- Equipped with blast doors each made of 5 sheets of $\frac{3}{4}$-inch exterior plywood (see Fig. D.15) bonded with resin glue and nailed together with $4\frac{1}{2}$ in. nails. The nails should be driven on 4-in. spacings and their protruding ends should be clinched (bent over). The blast doors must be secured against being yanked open by negative pressure ("suction") by securing them with a strong wire bridle (see Fig. D.14), and with the lower, fixed wire strongly connected near the bottom of the entry to all of the vertical poles on one side, as shown in Fig. D.14.

- Provided with an adequate ventilation pump and with ventilation openings protected against blast by expedient blast-valves (Fig. D.18) installed in the vertical entries as shown in Fig. D.19, to protect the air-intake and the air-exhaust openings. (Ventilation openings should be as far as practical from buildings and combustible materials. Manually closed ventilation openings are NOT effective at the 50-psi overpressure range of most weapons, because there is insufficient time to close them between the arrival of

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the warning light from the explosion and the arrival of the blast wave.)

- Made with the roof poles covered by a yielding layer of brush or limbs about 6 inches thick, or of innerspring mattresses. This yielding layer in turn should be covered with bedsheets or other strong cloth, to increase the effectiveness of protective earth arching. Brush or limbs should be laid in 3 layers with sticks of the middle layer perpendicular to those of the other two layers.

- Covered with 5 feet of earth, sloped no steeper than 10°.

- Provided with additional shielding materials in the entryways, as shown in Fig. D.20. Such shielding would be needed to prevent occupants from receiving possibly incapacitating or fatal doses of initial nuclear radiation through the entryways at the 50-psi overpressure range, if the shelter is subjected to the effects of a weapon that is one megaton, *or larger,* in explosive yield.

Damp earth serves better for neutron shielding material than dry earth and can be substituted for water as shielding material if sufficient water containers are not available. (At the 50-psi overpressure range from explosions *smaller* than one megaton, the entry and shielding shown in Fig. D.20 may not provide adequate protection against initial nuclear radiation.)

When the shelter is readied for rapid occupancy, the shelter-ventilating KAP is secured against the ceiling, and the bags of earth in the doorway (under the KAP) are removed. Persons entering the shelter would stoop to go under the platform adjacent to the vertical entry. This platform is attached to vertical wall-poles of the horizontal entry and supports shielding water and earth. When all except the person who will shut and secure the blast door are inside the shelter room, occupants should quickly begin to place bags of earth in the doorway. When the attack has begun, the whole doorway can be closed with bags of earth or other dense objects until ventilation is necessary.

The entries of other types of blast shelters can be shielded in similar ways.

- Protected against fire by being built sufficiently distant from buildings and flammable vegetation and by having its exposed wood covered. For maximum expedient protection against ignition by the thermal radiation from a large explosion, all exposed wood should be free of bark, coated with wet mud or damp slaked lime (whitewash), and covered with aluminum sheet metal or foil to reflect heat. (Most of the thermal radiation from an explosion that was 1 megaton or larger would reach the 50-psi overpressure range after the blast wave had arrived and had torn the expedient protective coverings from the wood. However, as has been observed in megaton nuclear weapon tests, the dust cloud first produced by the popcorning effect and later by the blast winds would screen solid wood near the ground so effectively against thermal radiation that it would not be ignited, provided it had been initially protected as described above.)

PRECAUTIONS FOR OCCUPANTS OF BLAST SHELTERS

Although a well constructed blast shelter may be undamaged at quite high overpressure ranges, its occupants may be injured or killed as a result of rapid ground motions that move the whole shelter several inches in a few thousandths of a second. Rapid ground motions are not likely to cause serious injuries unless the shelter is in an area subjected to 30-psi or greater blast effects. To prevent possible injury, when the occupants of high-protection blast shelters are expecting attack they should avoid:

- Having their heads close to the ceiling. The "air slap" of the air-blast wave may push down the earth and an undamaged shelter much more rapidly than a person can fall. If one's head were to be only a few inches from the ceiling, a fractured skull could result.

- Leaning against a wall, because it may move very rapidly, horizontally as well as vertically.

- Sitting or standing on the floor, because ground shock may cause the whole shelter (including the floor) to rise very fast and injure persons sitting or standing on the floor. The safest thing to do is to sit or lie in a securely suspended, strong hammock or chair, or on thick foam rubber such as that of a mattress, or on a pile of small branches.

In dry areas or in a dry expedient shelter, ground shock may produce choking dust. Therefore, shelter occupants should be prepared to cover their faces with towels or other cloth, or put on a mask. If an attack is expected, they should keep such protective items within easy reach.

B434-24 – Staff Summary

Proponent: Michael McCabe, representing self

Brief Description: Adds new definition and requirements for bomb shelters.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

First GSW Meeting — 7/29/2025

Support: None

Opposition: Steve Shapiro, Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA); Kyle Kratzer, representing himself; David Beahm, Virginia Building and Code Officials Association (VBCOA); and Ron Clements, Chesterfield County.

Discussion:

Florin Moldovan (DHCD staff) – We worked with the proponent to some extent to help him put this within the context of the code. Staff are not speaking to the merits or technical aspects of the proposal. Provides overview of the proposal.

a. **Steve Shapiro**, opposed. This should go through the ICC process.
b. **Kyle Kratzer**, the number one thing that this proposal could use to make it more palatable is to reduce the amount of code language in the definition. At the very least, it would need some code sections instead of putting so much of that in the definition. This will require considerable effort to clarify the intent.
c. **David Beahm**, VBCOA building code committee is in opposition. This should go through a full vetting process.
d. **Ron Clements,** unsure what this applies to. Would this apply to every building ever built? There's no code language or mandatory language here.

DHCD Staff Note: N/A

B706.3-24

IBC: 706.3

Proponents: Shahriar Amiri, representing Arlington County, VA (samiri@arlingtonva.us)

2024 International Building Code

Revise as follows:

706.3 Materials. *Fire walls* shall be of any approved ~~noncombustible materials.~~ materials permitted by the building type of construction. ~~Exception: Buildings of Type V construction~~

Reason Statement: This language is consistent with other code references that define approvable types of materials permitted in rated partitions and barriers. It also allows firewalls to be constructed with the materials permitted with a building's construction type improving building constructability by allowing consistent construction materials with equivalent expansion and contraction properties.

Cost Impact: The code change proposal will decrease the cost

This will reduce the cost of construction by allowing Type III and IV fire walls to be constructed with the same materials used for the building type of construction.

B706.3-24 – Staff Summary

Proponent: Shahriar Amiri, Arlington County

Brief Description: Allows fire walls to be constructed of any materials permitted by the building type of construction. Currently, they must be constructed of noncombustible materials, except for buildings of Type V construction.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting – 01/06/2026

Support: None

Opposition: Dan Willham**,** Fairfax County and Virginia Building and Code Officials Association (VBCOA); and Andrew Milliken, Stafford County Fire Marshal's Office and Virginia Fire Services Board (VFSB) Codes and Standards Committee.

Discussion:

Shahriar Amiri provided an overview of the proposal.

a. **Dan Willham** argued that the proposal conflicts with existing provisions for fire walls which can allow the use of Fire Retardant Treated (FRT) lumber.
b. **Shahriar A** countered that UL or Warnock Hersey have not tested any assemblies using FRT, so you cannot just use FRT to build a fire wall.
c. **Andrew Milliken** expressed that the proposal basically deletes the section and doesn't add anything.

DHCD Staff Note: N/A

B903.2.1.2-24

VCC: [F] 903.2.1.2, SECTION 202

Proponents: Richard Gordon, representing Hanover County (rtgordon@hanovercounty.gov)

2021 Virginia Construction Code

Revise as follows:

[F] 903.2.1.2 Group A-2. An *automatic sprinkler system* shall be provided throughout stories containing Group A-2 occupancies and throughout all stories from the Group A-2 occupancy to and including the *levels of exit discharge* serving that occupancy where one of the following conditions exists:

1. The *fire area* exceeds 5,000 square feet (464 m^2).
2. The fire area has an occupant load of 100 or ~~more in *night clubs* or 300 or more in other Group A-2occupancies.~~ more.
3. The *fire area* is located on a floor other than a *level of exit discharge* serving such occupancies.

Delete without substitution:

~~**NIGHT CLUB.** Any *building* in which the main use is a place of public assembly that provides exhibition, performance or other forms of entertainment; serves alcoholic beverages; and provides music and space for dancing.~~

Reason Statement: Virginia has historically modified IBC section 903.2.1.2 to allow sprinkler systems to be omitted in A-2 occupancies for up to 300 people, with the exception of night clubs. While this modification potentially reduces cost for restaurants and similar uses with occupant loads between 100 and 300, the night club definition has caused confusion and misapplication by code officials. Some code officials apply the night club definition to banquet halls and other spaces that have the components listed in the definition: alcohol, music and a space for dancing. Other code officials have evaluated use in a broader sense and assigned an occupancy classification based on the actual use of the space. The result is that in some localities, a banquet hall with between 100 and 300 occupants requires automatic sprinklers, while in others, sprinklers are not required until the occupant load exceeds 300.

By eliminating the exception, the inconsistency in application of 903.2.1.2 will be eliminated, and the VCC will be more consistent with the ICC. The night club definition can be removed as the distinction between night clubs and other A-2 uses is no longer pertinent.

Cost Impact: The code change proposal will increase the cost This proposal will increase the cost of construction for A-2 occupancies with occupant loads between 100 and 300 as these spaces will now require automatic sprinklers.

B903.2.1.2-24 – Staff Summary

Proponent: Richard Gordon, Hanover County

Brief Description: Requires installation of an automatic sprinkler system in Group A-2 occupancies with an occupant load of 100 or more. Reducing the existing occupant load threshold from 299 to 99.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

First GSW Meeting — 7/29/2025

Support: None

Opposition: Steve Shapiro, representing himself; David Beahm, Virginia Building and Code Officials Association (VBCOA); and Sean Farrell, Prince William County.

Discussion:

a. **Richard Gordon** – Asks to discuss B903.2.1.2-24 and B907.2.1.1-24 together as they are companion proposals. Provides overviews of the proposals.
   i. **Dennis Hart** (Fairfax County) – Question for B907.2.1.1-24: How does the code official determine the average ambient noise when determining compliance?
      1. **Richard G** – Great question. NFPA 72 has a test method, but it doesn't provide much usability here.
   ii. **Steve Shapiro** – Speaking for self, referencing B903.2.1.2-24. This is a big leap where restaurants that wouldn't previously need sprinklers now need to be sprinklered. Agrees the definition of night club needs work. Opposes this proposal. AOBA has no position.
   iii. **David Beahm** – Representing VBCOA's building code committee. A change of use where a restaurant would go from a smaller restaurant to a larger one could be detrimental, and the cost impact would be astronomical. Unsure if there is any justification for this. VBCOA's building code committee is opposed to both.
   iv. **Sean Farrell** (Prince William County) – Opposed to both. Asks the proponent to come up with data to support the change.
   v. **Jeff Brown** (DHCD staff) – Do you want to move forward with getting a vote on this?
   vi. **Richard G** – If I want to submit something that's totally different version just to address the night club clarification, I can do that separately. b. Non-consensus

DHCD Staff Note: N/A

B906.1-24

VCC: [F] 906.1

Proponents: Morgan Hurley, Senez Consulting, Inc., representing Fire Equipment Manufacturers' Association (mhurley@senezco.com)

2021 Virginia Construction Code

Revise as follows:

[F] 906.1 Where required. Portable fire extinguishers shall be installed in all of the following locations:

1. In Groups A, B, E, F, H, I, M, R-1, R-2, R-4, and S occupancies.

   Exceptions:

   1. ~~In Groups A, B, and E occupancies equipped throughout with quick response sprinklers, portable fire extinguishers shall be required only in locations specified in Items 2 through 6.~~

      In Group R-2 occupancies, portable fire extinguishers shall be required only in locations specified in Items 2 through 6 where each dwelling unit is provided with a portable fire extinguisher having a minimum rating of 1-A:10-B:C.

   2. In Group E occupancies, portable fire extinguishers shall be required only in locations specified in Items 2 through 6 where each classroom is provided with a portable fire extinguisher having a minimum rating of 2-A:20-B:C.

   3. In storage areas of Group S Occupancies where forklift, powered industrial truck or powered cart operators are the primary occupants, fixed extinguishers, as specified in NFPA 10, shall not be required where in accordance with all of the following:

3.1.	Use of vehicle-mounted extinguishers shall be approved by the fire code official.
3.2.	Each vehicle shall be equipped with a 10-pound, 40A:80B:C extinguisher affixed to the vehicle using a mounting bracket approved by the extinguisher manufacturer or the fire code official for vehicular use.
3.3.	Not less than two spare extinguishers of equal or greater rating shall be available on site to replace a discharged extinguisher.
3.4	Vehicle operators shall be trained in the proper operation, use and inspection of extinguishers.
3.5.	Inspections of vehicle-mounted extinguishers shall be performed daily.

   4. In Group I-3 occupancies, portable fire extinguishers shall be permitted to be located at staff locations, and the access to such extinguishers shall be permitted to be locked.

2. Within 30 feet (9144 mm) distance of travel from commercial cooking equipment and from domestic cooking equipment in Group I-1; I-2, Condition 1; and R-2 college *dormitory* occupancies.
3. In areas where flammable or *combustible liquids* are stored, used or dispensed.
4. On each floor of structures under construction, except Group R-3 occupancies, in accordance with Section ~~3315.1~~ 3306.6 of the International Fire Code.
5. Where required by the *International Fire Code* sections indicated in Table 906.1.
6. Special-hazard areas, including but not limited to laboratories, computer rooms and generator rooms, where required by the fire code official.

   Exception: Portable fire extinguishers are not required at normally unmanned Group U occupancy buildings or structures where a portable fire extinguisher suitable to the hazard of the location is provided on the vehicle of visiting personnel.

Reason Statement: The International Building Code/International Fire Code included an exception for portable fire extinguishers in A, B and E occupancies equipped throughout with quick response sprinklers through the 2009 edition. This exception was identical to current (2021) VCC/VSFPC 906.1, exception 1.

The exception for A, B and E occupancies equipped throughout with quick response sprinklers was removed from the IBC/IFC beginning with the 2012 editions. However, Virginia has maintained this exception as a state amendment. This proposal seeks to align the VCC/VSFPC requirement for portable fire extinguishers with that in the IBC/IFC. The code change proposal that removed this exception

from the IBC (F94-09/10) stated, in part: "*Fire extinguishers have historically been the first line of defense for small, controllable fires. They are intended to be used for fires of limited size and easily controlled. If a fire is discovered in its early stages the most effective means of protecting life and preventing property loss is to sound an alarm and then to control and/or extinguish the incipient stage fire with a portable fire extinguisher. To simply wait for the fire to grow to size large enough for a sprinkler head to activate is contrary to lessons and guidance from the fire service and fire protection professionals. Since fire extinguishers provide a first line of defense vs. sprinklers, it remains unclear as to the justification for this exception. In that light, the Exception 1 to Section 906.1 should be deleted*."

This code change would also require portable fire extinguishers in R-2 occupancies, which is required by the IBC, but is not required by the VCC (the VCC only requires portable fire extinguishers in R-1 and R-4 residential occupancies.) However, the IBC/IFC have exceptions (exception 1) that allow the extinguishers to be located in dwelling units.

Research conducted on behalf of the Fire Equipment Manufacturer's Association ("*A Review of the Impact of Fire Extinguishers in Reducing the Carbon Footprint of Building Fires*", dated March 27. 2023) found that 4.5% of residential fires that were not reported to the fire department were extinguished by occupants who used portable fire extinguishers. In industrial occupancies, 38% of fires were suppressed using portable fire extinguishers. These statistics show that portable fire extinguishers can effectively be used to suppress small fires by building occupants. The current VCC/VSFPC 906.1, exception 2 (which allows portable fire extinguishers in I-3 occupancies to be located in locked staff areas) is proposed to be maintained as a new exception 4 to VCC/VSFPC 906.1.

Cost Impact: The code change proposal will increase the cost This proposal would have a minor cost increase by requiring portable fire extinguishers in A, B, and E occupancies equipped throughout with quick response sprinklers and R-2 occupancies.

B906.1-24 – Staff Summary

Proponent: Morgan Hurley, Fire Equipment Manufacturer's Association

Brief Description: Requires portable fire extinguishers in group R-2 occupancies and deletes an existing Virginia amendment which exempts groups A, B and E occupancies from the requirement to provide portable fire extinguishers, if the buildings are equipped throughout with quick response sprinklers.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Second GSW Meeting — 10/3/2025

Support: Andrew Milliken, Stafford County Fire Marshal's Office, Virginia Fire Services Board (VFSB) Codes and Standards Committee.

Opposition: Steve Shapiro, Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA); Dan Willham, Fairfax County and Virginia Building and Code Officials Association (VBCOA); and Shahriar Amiri, Arlington County.

Discussion:

Jeff Brown (DHCD staff) provided an overview of the proposal and the associated floor modification shared on the screen.

Andrew Milliken expressed support.

Steve Shapiro reiterated comments from the 2nd SFPC SWG meeting.

*i. Comments from 2nd SFPC SWG meeting: **Steve S** noted that striking A, B, and E occupancies has been proposed to be stricken for the past 5 code cycles and that the Board of Housing has rejected it every time. AOBA will be speaking again in opposition at the Board of Housing and Community Development meeting.*

Dan Willham noted that the VBCOA building code committee opposes this proposal.

S**hahriar Amiri** stated that this proposal only increases costs without solving a problem.

DHCD Staff Note:

This proposal and its companion SFPC proposal FP906.1-24 were reviewed together by stakeholders at the second GSW meeting on October 3, 2025, and both received a Non-Consensus recommendation.

B907.2.1.1-24

VCC: 907.2.1.1; IBC: [F] 907.5.2.1.2

Proponents: Richard Gordon, representing Hanover County (rtgordon@hanovercounty.gov)

2021 Virginia Construction Code

Revise as follows:

907.2.1.1 System initiation in Group A occupancies with an occupant load of 1,000 or more ~~and in certain night clubs.~~ Activation of the fire alarm in Group A occupancies with an occupant load of 1,000 or more ~~and in *night clubs* with an occupant load of 300 or more~~ shall initiate a signal using an emergency voice and alarm communications system in accordance with Section 907.5.2.2 .

Exception: Where approved, the prerecorded announcement is allowed to be manually deactivated for a period of time, not to exceed 3 minutes, for the sole purpose of allowing a live voice announcement from an approved, constantly attended location.

2024 International Building Code

Revise as follows:

[F] 907.5.2.1.2 Maximum sound pressure. The total sound pressure level produced by combining the ambient sound pressure level with all audible notification appliances operating shall not exceed 110 dBA at the minimum hearing distance from the audible appliance. Where the average ambient noise in Group A occupancies exceeds 105 dBA, a system arranged to stop or reduce ambient noise shall be provided in accordance with NFPA 72. In all other occupancies, where the average ambient noise is greater than 105 dBA, *visible alarm notification appliances* shall be provided in accordance with NFPA 72 and *audible alarm notification appliances* shall not be required.

Reason Statement: The current VCC provisions differentiate night clubs from other A occupancies, both with respect to sprinkler provisions and alarm annunciation, but the concerns with night clubs are also present in other A occupancies. Theaters, arenas and other A occupancies often have high ambient noise levels and distracting lighting that could obscure notification appliances. This proposal attempts to address those concerns in all A occupancies by requiring a system to reduce or turn off sources of ambient noise, while also eliminating the need to treat night clubs differently. This proposal is submitted in conjunction with a proposal to require automatic sprinklers in all A-2 occupancies with an occupant load greater than 100.

Cost Impact: The code change proposal will increase the cost Night clubs with 300-1000 occupants would no longer need a voice alarm system, but would likely require a system to reduce or eliminate sources of ambient noise. Other A occupancies where ambient noise exceeds 105 dBA would also incur the cost of this system.

B907.2.1.1-24 – Staff Summary

Proponent: Richard Gordon, Hanover County

Brief Description: Requires fire alarm systems in all Group A occupancies where ambient noise exceeds 105 dBA to reduce or turn off sources of ambient noise.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

First GSW Meeting — 7/29/2025

Support: None

Opposition: Steve Shapiro, representing himself; David Beahm, Virginia Building and Code Officials Association (VBCOA); and Sean Farrell, Prince William County.

Discussion:

a. **Richard Gordon** – Asks to discuss B903.2.1.2-24 and B907.2.1.1-24 together as they are companion proposals. Provides overviews of the proposals.
   i. **Dennis Hart** (Fairfax County) – Question for B907.2.1.1-24: How does the code official determine the average ambient noise when determining compliance?
      1. **Richard G** – Great question. NFPA 72 has a test method, but it doesn't provide much usability here.
   ii. **Steve Shapiro** – Speaking for self, referencing B903.2.1.2-24. This is a big leap where restaurants that wouldn't previously need sprinklers now need to be sprinklered. Agrees the definition of night club needs work. Opposes this proposal. AOBA has no position.
   iii. **David Beahm** – Representing VBCOA's building code committee. A change of use where a restaurant would go from a smaller restaurant to a larger one could be detrimental, and the cost impact would be astronomical. Unsure if there is any justification for this. VBCOA's building code committee is opposed to both.
   iv. **Sean Farrell** – Opposed to both. Asks the proponent to come up with data to support the change.
   v. **Jeff Brown** (DHCD staff) – Do you want to move forward with getting a vote on this?
   vi. **Richard G** – If I want to submit something that's totally different version just to address the night club clarification, I can do that separately. b. Non-consensus

DHCD Staff Note:

This proposal is similar to proposal B907.5.2.1.2-24, which was reviewed by stakeholders at the third

GSW meeting on January 6, 2026, and received a Non-Consensus recommendation. The excerpt from the January 6, 2026, meeting summary pertaining to B907.5.2.1.2-24 is provided below.

January 6, 2026, GSW Meeting Summary Excerpt

Support: Dan Willham, Fairfax County, Virginia Building and Code Officials Association (VBCOA); and Andrew Milliken, Stafford County Fire Marshal's Office, Virginia Fire Services Board (VFSB) Codes and Standards Committee.

Opposition: David Beahm, Warren County, VBCOA.

Paul Messplay (on behalf of proponent) provided an overview of the proposal.

i. **Steve Shapiro** [Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA)] asked how much per square foot this proposal would increase cost.
ii. **Paul Messplay** replied that he did have that information.
iii. **Andrew Milliken** [Stafford County Fire Marshal's Office, Virginia Fire Services Board (VFSB)] summarized his understanding to be that a switch would be integrated with the building operation system to shut down the ambient noise.
iv. **Gregg Black** (George Mason University) asked how this system is going to tie into sound systems that are brought into A occupancies as part of the traveling shows and are not permanently built into the building.
v. **Shahriar Amiri** (Arlington County) suggested that the visible alarms requirement in the code section are the solution.
vi. **Andrew Milliken** contributed that he does not believe the intent was to apply the requirements to temporary arrangements and configurations. An argument can be made that the average ambient noise is not going to be greater than 105 dBA for most events, and the ambient noise will only be greater than 105 dBA occasionally which would negate this requirement from kicking in.
vii. **Michael Dellinger** (Albemarle County, VBCOA Region IV) commented that this system would reduce the voice emergency response volume.

B907.5.2.1.2-24

IBC: [F] 907.5.2.1.2

Proponents: Richard Gordon, Hanover County, representing Self (rtgordon@hanovercounty.gov)

2024 International Building Code

Revise as follows:

[F] 907.5.2.1.2 Maximum sound pressure. The total sound pressure level produced by combining the ambient sound pressure level with all audible notification appliances operating shall not exceed 110 dBA at the minimum hearing distance from the audible appliance. Where the average ambient noise in an A occupancy exceeds 105 dBA, a system arranged to stop or reduce ambient noise shall be provided in accordance with NFPA 72. In all other occupancies, where the average ambient noise is greater than 105 dBA, *visible alarm notification appliances* shall be provided in accordance with NFPA 72 and *audible alarm notification appliances* shall not be required.

Reason Statement: Theaters, arenas and other A occupancies have amplified sound and distracting lighting that could obscure notification appliances. This issue is exacerbated in large A occupancies that use voice communication – the audible signal is indistinguishable from the ambient noise. Rather than simply omitting audible signals, NFPA 72 has guidance that would allow alarm designers to incorporate sound attenuation into the alarm design, and make the alarm notification devices effective. Many designers already include this function in spaces dedicated to musical performances and similar uses.

As stated in NFPA 72 explanatory material:

Reducing the background noise is a viable alternative to providing a fire alarm system with a high level of audio output. In venues such as nightclubs, concert halls, and theaters, stopping the background noise and controlling the lighting to create a sudden and noticeable change in the environment that will get people’s attention is advised.

Cost Impact: The code change proposal will increase the cost The addition of relays and associated wiring to turn off sources of amplified sound will increase construction cost for assembly occupancies where designers have not already incorporated this system into the design.

B907.5.2.1.2-24 – Staff Summary

Proponent: Richard Gordon, Hanover County, representing self

Brief Description: Requires fire alarm systems in all Group A occupancies where ambient noise exceeds 105 dBA to reduce or turn off sources of ambient noise.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting — 01/06/2026

Support: Dan Willham, Fairfax County, Virginia Building and Code Officials Association (VBCOA); and Andrew Milliken, Stafford County Fire Marshal's Office, Virginia Fire Services Board (VFSB) Codes and Standards Committee.

Opposition: David Beahm, Warren County, VBCOA.

Discussion:

Paul Messplay (on behalf of proponent) provided an overview of the proposal.

i. **Steve Shapiro** [Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA)] asked how much per square foot this proposal would increase cost.
ii. **Paul Messplay** replied that he did have that information.
iii. **Andrew Milliken** summarized his understanding to be that a switch would be integrated with the building operation system to shut down the ambient noise.
iv. **Gregg Black** (George Mason University) asked how this system is going to tie into sound systems that are brought into A occupancies as part of the traveling shows and are not permanently built into the building.
v. **Shahriar Amiri** (Arlington County) suggested that the visible alarms requirement in the code section are the solution.
vi. **Andrew Milliken** contributed that he does not believe the intent was to apply the requirements to temporary arrangements and configurations. An argument can be made that the average ambient noise is not going to be greater than 105 dBA for most events, and the ambient noise will only be greater than 105 dBA occasionally which would negate this requirement from kicking in.
vii. **Michael Dellinger** (Albemarle County, VBCOA Region IV) commented that this system would reduce the voice emergency response volume.

DHCD Staff Note:

This proposal is similar to proposal B907.2.1.1-24, which was reviewed by stakeholders at the first GSW meeting on July 29, 2025, and received a Non-Consensus recommendation. The excerpt from the July 29, 2025, meeting summary pertaining to B907.2.1.1-24 is provided below.

July 29, 2025, GSW Meeting Summary Excerpt

Support: None

Opposition: Steve Shapiro, representing himself; David Beahm, Virginia Building and Code Officials Association (VBCOA); and Sean Farrell, Prince William County.

a. **Richard Gordon** – Asks to discuss B903.2.1.2-24 and B907.2.1.1-24 together as they are companion proposals. Provides overviews of the proposals.
    i. **Dennis Hart** (Fairfax County) – Question for B907.2.1.1-24: How does the code official determine the average ambient noise when determining compliance?
        1. **Richard G** – Great question. NFPA 72 has a test method, but it doesn't provide much usability here.
    ii. **Steve Shapiro** – Speaking for self, referencing B903.2.1.2-24. This is a big leap where restaurants that wouldn't previously need sprinklers now need to be sprinklered. Agrees the definition of night club needs work. Opposes this proposal. AOBA has no position.
    iii. **David Beahm** – Representing VBCOA's building code committee. A change of use where a restaurant would go from a smaller restaurant to a larger one could be detrimental, and the cost impact would be astronomical. Unsure if there is any justification for this. VBCOA's building code committee is opposed to both.
    iv. **Sean Farrell** (Prince William County) – Opposed to both. Asks the proponent to come up with data to support the change.
    v. **Jeff Brown** (DHCD staff) – Do you want to move forward with getting a vote on this? vi. Richard G – If I want to submit something that's totally different version just to address the night club clarification, I can do that separately. b. Non-consensus

B917.1-24

VCC: SECTION 917, [F] 917.1, SECTION 202

Proponents: Gregg Black, representing George Mason University (gblack2@gmu.edu), Virginia Emergency Management Association Institutions of Higher Education Caucus

2021 Virginia Construction Code

SECTION 917
MASS NOTIFICATION SYSTEMS

Revise as follows:

[F] 917.1 College and university campuses. Prior to construction of a new building requiring a fire alarm system on a multiple-building college or university campus having a cumulative building *occupant load* of 1,000 or more, a mass notification risk analysis shall be conducted in accordance with NFPA ~~72.~~ 72 and shall be approved by the Emergency Management Coordinator. Where the risk analysis determines a need for mass notification, an *approved* mass notification system shall be provided in accordance with the findings of the risk analysis.

SECTION 202 DEFINITIONS. Emergency Management Coordinator. The person appointed by their respective college or university to oversee Emergency Management for the college or university campus.

Reason Statement: College and university campuses have long been required to have distributed recipient mass notification systems since the Jeanne Clery Act was passed by the federal government. Further, Virginia institutions are required by the Code of Virginia to have emergency broadcast systems on campus (23.1-803). This building code requirement for additional of mass notification does not take into account the other legal requirements and current mass notification systems that are already in place at institutions across the commonwealth. The risk assessment that is required for compliance with this code needs to be reviewed and approved by the emergency manager coordinator which every state institution is required to have per Executive Order 41 (2019), and private institutions have also appointed. With different architects being used on different projects, university's run the risk of risk assessments that don't align with each other or take into account the emergency planning that is done by the Emergency Managers at their respective institutions. This code modification would require that the risk assessments be approved by the experts at the various institutions who best understand the unique idiosyncrasies of emergency response at their particular institutions. If the risk assessment requires a mass notification system, then the Building Code Official would have oversight on the approval of the system and installation.

Cost Impact: The code change proposal will not increase or decrease the cost This code modification only clarifies who should be reviewing the assessment. There is no expectation that it will change the cost of the building.

Attached Files

- **Code Change Letter of Support.docx**
  https://va.cdpaccess.com/proposal/1411/2017/files/download/949/

August 27, 2025

Virginia Department of Housing and Community Development
600 E. Main Street, Suite 300
Richmond, VA 23219

Subject: Letter of Support for Proposed Code Change to Section [F] 917.1

Dear Members of the Board of Housing and Community Development,

On behalf of the Virginia Emergency Management Association (VEMA) Institutions of Higher Education (IHE) Caucus, I write in support of the proposed amendment to Section [F] 917.1 of the Virginia Uniform Statewide Building Code regarding mass notification risk assessments on college and university campuses.

The current code requires that a mass notification risk analysis be conducted and approved by the building code official. While this step is essential, we believe the process should also formally involve the institution's designated Emergency Management Coordinator. Emergency Managers play a critical role in coordinating emergency communications across a campus, ensuring integration with existing mass notification systems, and aligning with broader crisis communication protocols.

The proposed language would amend the section as follows (addition in bold):

[F] 917.1 College and university campuses.
Prior to construction of a new building requiring a fire alarm system on a multiple-building college or university campus having a cumulative building occupant load of 1,000 or more, a mass notification risk analysis shall be conducted in accordance with NFPA 72 **and shall be approved by the Emergency Manager Coordinator.** Where the risk analysis determines a need for mass notification, an approved mass notification system shall be provided in accordance with the findings of the risk analysis.

This change is important because it ensures:

1. **Holistic Review:** Emergency Managers are responsible for campus-wide emergency preparedness and communication planning. Their involvement ensures that new building systems are consistent with existing notification platforms and communication strategies.
2. **Operational Coordination:** While building code officials review compliance with technical standards, Emergency Managers evaluate operational realities of how notifications are issued during crises, helping close the gap between compliance and effective emergency response.
3. **Enhanced Safety:** Integration between system design and operational use strengthens emergency response capabilities and ultimately enhances the safety of students, faculty, staff, and visitors.

As a statewide caucus representing emergency management professionals at Virginia's colleges and universities, we strongly believe that adding the Emergency Management Coordinator to the approval process is a critical step in advancing both safety and operational effectiveness on our campuses.

We appreciate your consideration of this proposal and stand ready to provide additional perspective or technical input as needed.

Sincerely,



Peter McCann
Chair, VEMA Institutions of Higher Education Caucus

Public Comments (PCH) for: B917.1-24

Discussion by Gregg Black

Aug 27, 2025 13:00 UTC

College and university campuses have long been required to have distributed recipient mass notification systems since the Jeanne Clery Act was passed by the federal government. Further, Virginia institutions are required by the Code of Virginia to have emergency broadcast systems on campus (23.1-803). This building code requirement for additional of mass notification does not take into account the other legal requirements and current mass notification systems that are already in place at institutions across the commonwealth. The risk assessment that is required for compliance with this code needs to be reviewed and approved by the emergency manager coordinator which every state institution is required to have per Executive Order 41 (2019), and private institutions have also appointed. With different architects being used on different projects, university's run the risk of risk assessments that don't align with each other or take into account the emergency planning that is done by the Emergency Managers at their respective institutions. This code modification would require that the risk assessments be approved by the experts at the various institutions who best understand the unique idiosyncrasies of emergency response at their particular institutions. If the risk assessment requires a mass notification system, then the Building Code Official would have oversight on the approval of the system and installation.

Proposal # 1411

B917.1-24 – Staff Summary

Proponent: Gregg Black, representing George Mason University, Virginia Emergency Management Association Institutions of Higher Education Caucus

Brief Description: Adds a new definition for "Emergency Management Coordinator" and requires mass notification risk analyses for certain university campuses to be approved by this coordinator.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Second GSW Meeting — 10/03/2025

Support: Chris Barfield, University of Virginia, Building Official's Office.

Opposition: Dan Willham, Fairfax County and Virginia Building and Code Officials Association (VBCOA).

Discussion:

Gregg Black provided an overview of the proposal.

a. **Sean Farrell** (Prince William County) asked if there is an Emergency Management Coordinator (EMC) at every facility?
   i. **Gregg Black** replied that there is an EMC at every facility as required by Executive Order 41.

b. **Eric Mays** (Prince William County) asked what happens if the building official disagrees with the EMC, who is the final decision maker?
   i. **Gregg Black** stated the risk analysis would have to be approved by the EMC.
   ii. **Eric Mays** further inquired as to who has to approve the risk analysis under the current code?
   iii. **Gregg Black** noted that the current code is silent on who approves it.
   iv. **Eric Mays** stated that since the code is silent, this would be under the purview of the building official.
   v. **Gregg Black** replied in the affirmative.
   vi. **Eric Mays** asked if the proponent is intentionally usurping the power of the building official and giving it to someone else.
   vii. **Gregg Black** replied in the affirmative, further noting that the building official would have a say about what gets installed, to make sure that it's compliant with NFPA standards, but the risk analysis regarding how the system would be used and what the hazards and threats are

to the building, would be within the purview of the EMC. The risk assessment addresses the hazards that the campus would face and how communication happens between campus administration and the occupants of the buildings.

DHCD Staff Note:

This proposal is similar to proposal B917.1.1-24, which was reviewed by stakeholders at the third GSW meeting on January 6, 2026, and received a Non-Consensus recommendation. The excerpt from the January 6, 2026, meeting summary pertaining to B917.1.1-24 is provided below.

January 6, 2026, GSW Meeting Summary Excerpt

Support: Jared Hoernig, Virginia Emergency Management Association; Chris Barfield, University of Virginia, Building Official's Office; and Andrew Milliken, representing himself.

Opposition: Dan Willham, Fairfax County, Virginia Building and Code Officials Association (VBCOA).

Discussion:

Gregg Black provided an overview of the proposal which is a variation of proposal B917.1, which was heard during the October General Stakeholder Workgroup Meeting.

i. **Jared Hoernig** stated that this proposal connects the code official with a campus subject matter expert.
ii. **Chris Barfield** noted that the University of Virginia is already doing this.
iii. **Dan Willham** expressed that this is not something building officials should be regulating.

B917.1.1-24

IBC: SECTION 202 (New), SECTION 917, [F] 917.1, 917.1.1 (New)

Proponents: Gregg Black, representing George Mason University (gblack2@gmu.edu)

2024 International Building Code

Add new text as follows:

SECTION 202 DEFINITIONS.
EMERGENCY MANAGEMENT COORDINATOR. Professional responsible for developing, implementing, and coordinating an emergency management program.

SECTION 917
MASS NOTIFICATION SYSTEMS

[F] 917.1 College and university campuses. Prior to construction of a new *building* requiring a *fire alarm system* on a multiple-*building* college or university campus having a cumulative *building occupant load* of 1,000 or more, a mass notification risk analysis shall be conducted in accordance with NFPA 72. Where the risk analysis determines a need for mass notification, an *approved* mass notification system shall be provided in accordance with the findings of the risk analysis.

917.1.1 Coordination. The Building code official shall consult with the emergency management coordinator when a mass notification system is required.

Reason Statement: College and university campuses have long been required to have distributed recipient mass notification systems since the Jeanne Clery Act was passed by the federal government. Further, Virginia institutions are required by the Code of Virginia to have emergency broadcast systems on campus (23.1-803). This building code requirement for additional of mass notification does not take into account the other legal requirements and current mass notification systems that are already in place at institutions across the commonwealth. The risk assessment that is required for compliance with this code needs to be coordinated with the emergency manager coordinator which every state institution is required to have per Executive Order 41 (2019), and private institutions have also appointed.

With different architects being used on different projects, university's run the risk of risk assessments that don't align with each other or take into account the emergency planning that is done by the Emergency Managers at their respective institutions. This code modification would require that the risk assessments be coordinated with the experts at the various institutions who best understand the unique idiosyncrasies of emergency response at their particular institutions.

Cost Impact: The code change proposal will not increase or decrease the cost There is no expectation that it will change the cost of the building.

Attached Files

- **Code Change Letter of Support.docx**
  https://va.cdpaccess.com/proposal/1528/2225/files/download/1014/

August 27, 2025

Virginia Department of Housing and Community Development
600 E. Main Street, Suite 300
Richmond, VA 23219

Subject: Letter of Support for Proposed Code Change to Section [F] 917

Dear Members of the Board of Housing and Community Development,

On behalf of the Virginia Emergency Management Association (VEMA) Institutions of Higher Education (IHE) Caucus, I write in support of the proposed amendment to Section [F] 917 of the Virginia Uniform Statewide Building Code regarding mass notification risk assessments on college and university campuses.

The current code requires that a mass notification risk analysis be conducted and approved by the building code official. While this step is essential, we believe the process should also formally involve the institution's designated Emergency Management Coordinator. Emergency Managers play a critical role in coordinating emergency communications across a campus, ensuring integration with existing mass notification systems, and aligning with broader crisis communication protocols.

The proposed language would add the following language:

[F] 917.1.1 Coordination
The Building code official shall consult with the emergency management coordinator when a mass notification system is required.

This change is important because it ensures:

1. **Holistic Review:** Emergency Managers are responsible for campus-wide emergency preparedness and communication planning. Their involvement ensures that new building systems are consistent with existing notification platforms and communication strategies.
2. **Operational Coordination:** While building code officials review compliance with technical standards, Emergency Managers evaluate operational realities of how notifications are issued during crises, helping close the gap between compliance and effective emergency response.
3. **Enhanced Safety:** Integration between system design and operational use strengthens emergency response capabilities and ultimately enhances the safety of students, faculty, staff, and visitors.

As a statewide caucus representing emergency management professionals at Virginia's colleges and universities, we strongly believe that mass notification systems need to be coordinated with the Emergency Management Coordinator to advance both safety and operational effectiveness on our campuses.

We appreciate your consideration of this proposal and stand ready to provide additional perspective or technical input as needed.

Sincerely,



Peter McCann
Chair, VEMA Institutions of Higher Education Caucus

B917.1.1-24 – Staff Summary

Proponent: Gregg Black, representing George Mason University

Brief Description: Adds a new definition for "Emergency Management Coordinator" and requires the building official to consult with this coordinator when a mass notification system is required.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting — 01/06/2026

Support: Jared Hoernig, Virginia Emergency Management Association; Chris Barfield, University of Virginia, Building Official's Office; and Andrew Milliken, representing himself.

Opposition: Dan Willham, Fairfax County, Virginia Building and Code Officials Association (VBCOA).

Discussion:

Gregg Black provided an overview of the proposal which is a variation of proposal B917.1, which was heard during the October General Stakeholder Workgroup Meeting.

i. **Jared Hoernig** stated that this proposal connects the code official with a campus subject matter expert.
ii. **Chris Barfield** noted that the University of Virginia is already doing this.
iii. **Dan Willham** expressed that this is not something building officials should be regulating.

DHCD Staff Note:

This proposal is similar to proposal B917.1-24, which was reviewed by stakeholders at the second GSW meeting on October 3, 2025, and received a Non-Consensus recommendation. The excerpt from the October 3, 2025, GSW meeting summary pertaining to B917.1-24 is provided below.

October 3, 2025 GSW Meeting Summary Excerpt

Support: Chris Barfield, University of Virginia, Building Official's Office.

Opposition: Dan Willham, Fairfax County and Virginia Building and Code Officials Association (VBCOA).

Discussion:

Gregg Black provided an overview of the proposal.

a. **Sean Farrell** (Prince William County) asked if there is an Emergency Management Coordinator (EMC) at every facility?
    i. **Gregg Black** replied that there is an EMC at every facility as required by Executive Order 41.
b. **Eric Mays** (Prince William County) asked what happens if the building official disagrees with the EMC, who is the final decision maker?
    i. **Gregg Black** stated the risk analysis would have to be approved by the EMC.
    ii. **Eric Mays** further inquired as to who has to approve the risk analysis under the current code?
    iii. **Gregg Black** noted that the current code is silent on who approves it.
    iv. **Eric Mays** stated that since the code is silent, this would be under the purview of the building official.
    v. **Gregg Black** replied in the affirmative.
    vi. **Eric Mays** asked if the proponent is intentionally usurping the power of the building official and giving it to someone else.
    vii. **Gregg Black** replied in the affirmative, further noting that the building official would have a say about what gets installed, to make sure that it's compliant with NFPA standards, but the risk analysis regarding how the system would be used and what the hazards and threats are to the building, would be within the purview of the EMC. The risk assessment addresses the hazards that the campus would face and how communication happens between campus administration and the occupants of the buildings.

B918.1-24

VCC: 918.1, 918.2, 918.3, 918.4, 918.5

Proponents: Matthew J. Bonifant, representing BXP, Inc. (mbonifant@bxp.com)

2021 Virginia Construction Code

Revise as follows:

918.1 General. For localities utilizing public safety wireless communications, dedicated infrastructure to accommodate and perpetuate continuous in-building *emergency communication equipment* to allow *emergency public safety personnel* to send and receive emergency communications shall be provided in new *buildings* and structures in accordance with this section.

Exceptions:

1. *Buildings* of Use Groups A-5, I-4, within dwelling units of R-2, R-3, R-4, R-5, and U.
2. *Buildings* of Types IV and V construction without basements, that are not considered unlimited area buildings in accordance with Section 507 .
3. Above grade single story *buildings* of less than 20,000 square feet (1858 m^2).
4. *Buildings* or leased spaces occupied by federal, state, or local governments, or the contractors thereof, with security requirements where the building official has approved an alternative method to provide *emergency communication equipment* for *emergency public safety personnel*.
5. Where the *owner* provides technological documentation from a qualified individual that the structure or portion thereof does not impede emergency communication signals.
6. *Buildings* in localities ~~that do not provide the additional communication equipment required for the operation of the system~~ where the *localities* do not have in-building communications requirements.

~~**918.1.1**~~ **918.2 Installation.** In-building two-way emergency responder communication coverage systems shall comply with Sections 510.4 and 510.5 of the *International Fire Code*, except that the acceptance testing procedure required by ~~Section 510.5.4 of the *International Fire Code* and~~Section 918.4 shall be the responsibility of the ~~locality~~ *owner*. The building *owner* shall install cable, donor antenna, Bi-directional Amplifier (BDA), Distribution Antenna System (DAS), and all other required system components. The cable shall be installed in dedicated conduits, raceways, plenums, attics, or roofs, compatible for these specific installations as well as other applicable provisions of this code. ~~The *locality* shall be responsible for the installation of any additional communication equipment required for the operation of the system.~~

~~**918.1.3**~~ **918.3 Inspection.** In accordance with Section 113.3, all installations shall be inspected prior to concealment.

~~**918.2**~~ **918.4 Acceptance test.** Upon completion of installation, ~~after providing reasonable notice to the owner or their representative, emergency public safety personnel shall have the right during normal business hours, or other mutually agreed upon time, to enter onto the property to conduct~~
field tests to verify that the required level of radio coverage is present in accordance with the criteria in section 510.5.4 of the *International Fire Code* shall be conducted by the owner or owner's representative. A copy of the acceptance testing results and report shall be provided to the locality upon request. ~~Any noted deficiencies in the installation of the radiating cable, operational space, or other required emergency communications equipment shall be provided in an inspection report to the owner or the owner's representative.~~

~~**918.1.2**~~ **918.5 Operations.** The ~~*locality*~~ *owner* will assume all ~~responsibilities~~ responsibility ~~for the operation~~ to ensure compliance with code requirements ~~maintenance of~~ for the *emergency communication equipment*. The building *owner* shall provide sufficient operational space within the *building* to allow the *locality* access to and the ability to operate in-building *emergency communication equipment*.
The *owner shall be responsible for the emergency communication equipment.*

Reason Statement: Many modern buildings are constructed with concrete, steel, or low-emissivity glass that can block or degrade the radio signals resulting in areas within a building where the radio signals are weak or there is no signal. Typically, these issues only arise on the lower and sublevels of buildings resulting in many buildings only needing partial coverage. Wireless systems ensure coordination, communication, and certainty that radio signals are transmitted and received. The use of this modern communication technology provides effective and reliable communication, which is one of the most important aspects of any emergency response: the ability to communicate in any part of a building without fear of losing radio contact. The loss of radio coverage can result in critical messages not communicated or received, not only endangering emergency responders, but endangering building occupants. This code change has not eliminated the option for hard-wired fire department communications; it has added an option.

The change in code exception #6 grants relief where the locality does not intend to provide the wireless equipment. However, many developers and building owners have willingly paid for and installed these systems recognizing the benefits to the occupants and all emergency responders. In addition, developers and building owners recognize that many localities are only requesting systems to be installed where needed. This makes it easier and more time efficient for the owner to install a system.

Having the option to install a wireless system in a high-rise or other non-exempt building or structure provides the owner with a code path to utilize the technology. Outdated hardwired communications systems are overall, more expensive to purchase, install, and maintain, and less effective than a wireless system in coverage and flexibility because they are in specific and limited locations within a building that may not be easily accessible. A wireless communications system is monitored through the fire alarm system for integrity, thus providing public safety with a more reliable system to operate during emergency and non-emergency events. When a wireless system is installed, it is a more reliable system that provides better protection to those in the building for not only the firefighters trained to use hardwired communications systems, but for law enforcement and other agencies who are not trained or have access to hardwired communications systems. The reality is, hardwire communication systems are highly unlikely to be used by any emergency responder.

In addition, the parts of Section 918 were rearranged to reflect a more logical sequence of events that will occur.

Cost Impact: The code change proposal will increase the cost

In circumstances where the installation of a wireless communication system is not offset by the removal of a hardwired system, project costs will increase. In instances where the hardwire system is no longer required because of the installation of a wireless system, there will be a substantial cost saving to developers and building owners from installation through the life of the building. The cost benefit is especially apparent in high-rise buildings when installing a wireless communication system in lieu of two-way fire department communication equipment. The initial estimated cost to install a hardwired system in a 20-story building is $180K-$300K whereas the wireless system cost is estimated at $90K-$180K. In high-rise buildings, the elimination of hardwired two-way fire department communications systems more than covers the cost of designing and installing a wireless communication system.

The elimination of hardwired two-way fire department communication equipment provides not only cost savings related to design and installation, but it eliminates the recurring inspection, testing, maintenance and service costs to ensure these hardwired systems are operational. Over the life of the building, the building owner could incur tens of thousands of dollars in costs related to inspecting, testing, and maintaining two-way fire department communication equipment. However, the inspection, testing, and maintenance costs related to a wireless communication system are significantly less because the number of system components and potential problems are greatly reduced. Although the cost to maintain the wireless communication equipment is the responsibility of the building owner, the locality must monitor the operation, compliance, and system integrity. In other words, the locality must ensure the operational integrity of the system, and if determined there is an issue, the owner must engage their wireless contractor to take the appropriate action.

Attached Files

- **NAIOP Letter Modifications to VCC Section 918.pdf**
  https://va.cdpaccess.com/proposal/1477/2132/files/download/953/

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Teel Construction, Inc.
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Peterson Companies

October 8, 2025

Mr. Louie Berbert, Chair
Board of Housing and Community Development
600 East Main Street, Suite 300
Richmond, Virginia 23219

Subject: Support for Proposed Modifications to VCC Section 918
In-Building Emergency Communications Coverage

Dear Chair Berbert and Board Members:

I am writing on behalf of NAIOP Northern Virginia. We respectfully submit this letter in support of either of the proposed options to modify Section 918 of the 2024 Virginia Construction Code, included herein as Exhibit A and B, respectively. NAIOP is an association that represents commercial real estate developers, owners, investors and asset managers. Our members have touched the majority of the buildings, both private and public, in Northern Virginia through development, ownership, design, construction, etc., as well as a number of buildings throughout the Commonwealth.

These proposed changes reflect a forward-thinking approach to emergency communications infrastructure in new buildings and structures. Wireless systems offer distinct advantages over traditional hardwired fire department communication systems, including broader and more reliable coverage, reduced installation and maintenance costs, and greater adaptability to modern building designs. The revisions maintain the option for hardwired systems while introducing a viable alternative that aligns with current technology and emergency response needs. By clearly defining responsibilities for installation, inspection, and maintenance, the proposed code ensures accountability and system integrity without placing undue burden on localities or building owners. These updates will enhance public safety, support innovation in building design, and provide meaningful cost savings to developers and owners across Virginia.

We commend the proponents for their thoughtful and practical approach to improving emergency communications coverage. These changes will enhance public safety and provide meaningful cost savings to developers and owners across the Commonwealth.

NAIOP urges the adoption of these modifications to Section 918. Thank you for your continued commitment to improving Virginia's building codes.

Sincerely,

Martha Marks

President

1729 King Street, Suite 410, Alexandria, Virginia 22314 Tel: 703-845-7080 Fax: 703-845-7081

B918.1-24 – Staff Summary

Proponent: Matthew J. Bonifant, representing BXP, Inc.

Brief Description: Changes the responsibility for installation of in-building two-way emergency responder communication coverage systems from the locality to the building owner.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting — 01/06/2026

Support: Andrew Milliken, Stafford County Fire Marshal's Office and VFSB Codes and Standards Committee; Russell Furr, City of Alexandria Fire Marshal's Office; Gregg Fields, City of Alexandria; Dan Willham, Fairfax County and VBCOA; and Shahriar Amiri, Arlington County.

Opposition: Steve Shapiro, AOBA and VAMA; and Ron Clements, Chesterfield County and VBCOA Admin and Existing Building Code Committees.

Discussion:

Chris Sampl, on behalf of the proponent, provided an overview of the proposal and the associated floor modification. **Florin Moldovan** (DHCD staff) brought awareness to the group that DHCD staff has not had an opportunity to thoroughly review the floor modification due to the timing of submittal and invited stakeholders to review the floor modification thoroughly.

i. **Gregg Fields** expressed relief that the proposal shifts the acceptance testing responsibility from the locality to the owner.
ii. **Dan Willham** drew attention to the fact that his locality has done building code modifications to allow wireless communication systems.
iii. **Steve Shapiro** explained that the prior code split the responsibility between the owner and the locality. Now the responsibility is all on the owner and it is a huge cost that includes fees and maintenance tests.
iv. **Chris Sampl** pointed to Exception 6 of Section 918.1 and clarified that the intent is for all jurisdictions to opt out if they don't want to have in-building communication requirements.
v. **Ron Clements** indicated that jurisdictions requiring these systems are doing so outside of the requirements of the current code, and that Exception 6, as modified, is not doing what is being claimed it is doing. **Ron C** elaborated the way the proposal is currently written does not get the locality out of a requirement.

DHCD Staff Note:

This proposal conflicts with proposal B918.2-24, which was reviewed by stakeholders at the same GSW meeting and received a Non-Consensus recommendation. The excerpt from the January 6, 2026, meeting summary pertaining to B918.2-24 is provided below.

January 6, 2026, GSW Meeting Summary Excerpt

Support: Andrew Milliken, Stafford County Fire Marshal's Office and Virginia Fire Services Board (VFSB) Codes and Standards Committee; Chris Sampl, Fairfax County, Office of the Fire Marshal; and Steve Shapiro, Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA).

Opposition: Ron Clements, Chesterfield County and VBCOA Admin and Existing Building Code Committees; and Gregg Fields, City of Alexandria.

Discussion:

Chris Sampl, on behalf of the proponent, provided an overview of the proposal and the associated floor modification. **Florin Moldovan** (DHCD staff) brought awareness to the group that DHCD staff has not had an opportunity to thoroughly review the floor modification due to the timing of submittal and invited stakeholders to review the floor modification thoroughly.

i. **Doug Banks** (Henrico County) asked how this proposal differs from the present requirement for non-required equipment.
ii. **Andrew Milliken** explained that the difference between this proposal and the previous proposal is that this proposal establishes if a building owner chooses to provide non-required equipment, the acceptance testing of that equipment is now not the responsibility of the locality.
iii. **Chris Sampl** added that the proposal provides an avenue for wireless emergency communication without having to get a code modification. The majority of the country already allows wireless communication.
iv. **Steve Shapiro** remarked that if the system is voluntary then there is no opposition.
v. **Ron Clements** indicated that voluntary systems are already allowed in the code and there is no need for code sections all over the code covering maintenance and testing requirements for voluntary systems.
vi. **Andrew Milliken** countered that the code as currently written does not simply allow voluntary emergency communications without adding responsibility to both the owner and the locality. This takes responsibility off the locality since it is voluntary.

vii. **Ron Clements** stipulated that if the locality is not providing equipment, you're exempt from this section. Electively installing it, does not undo Exception 6.
viii. **Shahriar Amiri** (Arlington County) questioned why this section is different from anything else that is voluntary as addressed in Chapter 1. If you provide stairs that are not required, they still must meet certain safety criteria.
ix. **Gregg Fields** mentioned that it is hard to grasp a voluntary code requirement where the voluntary requirement is not an exception to a mandatory requirement.

B918.2-24

VCC: 918.2, 918.2.1 (New), 918.3, 918.4, 918.4.1 (New), 918.5, 918.5.1 (New)

Proponents: Matthew J. Bonifant, representing BXP, Inc. (mbonifant@bxp.com)

2021 Virginia Construction Code

Revise as follows:

~~**918.1.1**~~ **918.2 Installation.** In-building two-way emergency responder communication coverage systems shall comply with Sections 510.4 and 510.5 of the *International Fire Code*, except that the acceptance testing procedure ~~required by Section 510.5.4 of the *International Fire Code* shall be the responsibility of the *locality*~~ shall be in accordance with Section 918.4. The building *owner* shall install cable. The cable shall be installed in dedicated conduits, raceways, plenums, attics, or roofs, compatible for these specific installations as well as other applicable provisions of this code. The *locality* shall be responsible for the installation of any additional communication *equipment* required for the operation of the system.

Add new text as follows:

918.2.1 Voluntary wireless in-building emergency communications coverage. Voluntary installation of a wireless communications system by the *owner* or their representative shall be coordinated with and approved by the *locality*. In accordance with Sections 510.4 and 510.5 of the *International Fire Code* the system shall include the installation of cable, donor antenna, Bi-Directional Amplifier (BDA), and Distribution Antenna Systems (DAS), and any other required system components by the *owner*.

Revise as follows:

~~**918.1.3**~~ **918.3 Inspection.** In accordance with Section 113.3 , all installations shall be inspected prior to concealment.

~~**918.2**~~ **918.4 Acceptance test.** Upon completion of installation, after providing reasonable notice to the *owner* or their representative, *emergency public safety personnel* shall have the right during normal business hours, or other mutually agreed upon time, to enter onto the property to conduct field tests to verify that the required level of radio coverage is present at no cost to the *owner*. Any noted deficiencies in the installation of the radiating cable ~~or~~ , operational space, or other required *emergency communications equipment* shall be provided in an inspection report to the *owner* or the *owner's* representative.

Add new text as follows:

918.4.1 Voluntary wireless in-building communications coverage. When installed by the *owner,* the *owner* shall be responsible for the acceptance testing of the system in accordance with the *International Fire Code.*

Revise as follows:

~~**918.1.2**~~ **918.5 Operations.** The *locality* will assume all ~~responsibilities~~ responsibility for the operation ~~and maintenance~~ of the *emergency communication equipment*. The building *owner* shall provide sufficient operational space within the *building* to allow the *locality* access to and the ability to operate in-building *emergency communication equipment*.

Add new text as follows:

918.5.1 Voluntary wireless in-building communications coverage. When installed by the *owner*, the *owner* shall be responsible for the *emergency communication equipment.*

Reason Statement: Many modern buildings are constructed with concrete, steel, or low-emissivity glass that can block or degrade the radio signals resulting in areas within a building where the radio signals are weak or there is no signal. Typically, these issues only arise

on the lower and sublevels of buildings resulting in many buildings only needing partial coverage. Wireless systems ensure coordination, communication, and certainty that radio signals are transmitted and received. The use of this modern communication technology provides effective and reliable communication, which is one of the most important aspects of any emergency response: the ability to communicate in any part of a building without fear of losing radio contact. The loss of radio coverage can result in critical messages not communicated or received, not only endangering emergency responders, but endangering building occupants. This code change has not eliminated the option for hard-wired fire department communications; it has added an option.

Having the option to install a wireless system in a high-rise or other non-exempt buildings or structures provide the owner with a code path to utilize the technology. Outdated hardwired communications systems are overall, more expensive to purchase, install, and maintain, and less effective than a wireless system in coverage and flexibility because they are in specific and limited locations within a building that may not be easily accessible. A wireless communications system is monitored through the fire alarm system for integrity, thus providing public safety with a more reliable system to operate during emergency and non-emergency events. When a wireless system is installed, it is a more reliable system that provides better protection to those in the building for not only the firefighters trained to use hardwired communications systems, but for law enforcement and other agencies who are not trained or have access to hardwired communications systems. The reality is, hardwire communication systems are highly unlikely to be used by any emergency responder.

In addition, the parts of Section 918 were rearranged to reflect a more logical sequence of events that will occur.

Cost Impact: The code change proposal will not increase or decrease the cost

This is a voluntary program that owner's are not required to participate in. Below summarizes the cost impacts (and potential savings) if owner's opt in:

Installation of a wireless communication system instead of hardwired two-way fire department communications equipment provides a substantial cost saving to developers and building owners from installation through the life of the building. The cost benefit is especially apparent in high-rise buildings when installing a wireless communication system in lieu of two-way fire department communication equipment. The initial estimated cost to install a hardwired system in a 20-story building is $180K-$300K whereas the wireless system cost is estimated at $90K-$180K. In high-rise buildings, the elimination of hardwired two-way fire department communications systems more than covers the cost of designing and installing a wireless communication system.

The elimination of hardwired two-way fire department communication equipment provides not only cost savings related to design and installation, but it eliminates the recurring inspection, testing, maintenance and service costs to ensure these hardwired systems are operational. Over the life of the building, the building owner could incur tens of thousands of dollars in costs related to inspecting, testing, and maintaining two-way fire department communication equipment. However, the inspection, testing, and maintenance costs related to a wireless communication system are significantly less because the number of system components and potential problems are greatly reduced. Although the cost to maintain the wireless communication equipment is the responsibility of the building owner, the locality must monitor the operation, compliance, and system integrity. In other words, the locality must ensure the operational integrity of the system, and if determined there is an issue, the owner must engage their wireless contractor to take the appropriate action.

Attached Files

- **NAIOP Letter Modifications to VCC Section 918.pdf**
  https://va.cdpaccess.com/proposal/1479/2134/files/download/954/

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LeVar T. Crooms
United Bank
J. Caulley Deringer
Stream Realty Partners
Benjamin S. Eitan
Clark Construction Group, L.L.C.
Richard P. Fernicola
Stack Infrastructure
Nicholas C. Gregorios
Avison Young
Matthew F. Holbrook
St. John Properties, Inc.
Larlyn L. Jennings
L.F. Jennings
Jason J. Krawiecki
COPT Defense Properties
Megan M. Lantz
HITT Contracting, Inc.
Heather L. Nevin
CBRE
James D. Policaro
Lerner
G. Evan Pritchard
Wire Gill LLP
Jason C. Rascoe
Beacon Capital Partners
John E. Sadlik
J2H Partners
Jeremiah J. Watts
D|WATTS Construction
Katherine Pierce Yanushonis
TMG
Edward V. Zaptin
Cushman & Wakefield

Ex Officio – Developing Leaders
Molly K. Statler
PGAL Architects
Bryce B. Teel
Teel Construction, Inc.
R. Clark Tutwiler IV
Peterson Companies

October 8, 2025

Mr. Louie Berbert, Chair
Board of Housing and Community Development
600 East Main Street, Suite 300
Richmond, Virginia 23219

Subject: Support for Proposed Modifications to VCC Section 918
In-Building Emergency Communications Coverage

Dear Chair Berbert and Board Members:

I am writing on behalf of NAIOP Northern Virginia. We respectfully submit this letter in support of either of the proposed options to modify Section 918 of the 2024 Virginia Construction Code, included herein as Exhibit A and B, respectively. NAIOP is an association that represents commercial real estate developers, owners, investors and asset managers. Our members have touched the majority of the buildings, both private and public, in Northern Virginia through development, ownership, design, construction, etc., as well as a number of buildings throughout the Commonwealth.

These proposed changes reflect a forward-thinking approach to emergency communications infrastructure in new buildings and structures. Wireless systems offer distinct advantages over traditional hardwired fire department communication systems, including broader and more reliable coverage, reduced installation and maintenance costs, and greater adaptability to modern building designs. The revisions maintain the option for hardwired systems while introducing a viable alternative that aligns with current technology and emergency response needs. By clearly defining responsibilities for installation, inspection, and maintenance, the proposed code ensures accountability and system integrity without placing undue burden on localities or building owners. These updates will enhance public safety, support innovation in building design, and provide meaningful cost savings to developers and owners across Virginia.

We commend the proponents for their thoughtful and practical approach to improving emergency communications coverage. These changes will enhance public safety and provide meaningful cost savings to developers and owners across the Commonwealth.

NAIOP urges the adoption of these modifications to Section 918. Thank you for your continued commitment to improving Virginia's building codes.

Sincerely,

Martha Marks

President

1729 King Street, Suite 410, Alexandria, Virginia 22314 Tel: 703-845-7080 Fax: 703-845-7081

B918.2-24 – Staff Summary

Proponent: Matthew J. Bonifant, representing BXP, Inc.

Brief Description: Adds requirements applicable to voluntary installations of in-building two-way emergency responder communication systems.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting — 01/06/2026

Support: Andrew Milliken, Stafford County Fire Marshal's Office and Virginia Fire Services Board (VFSB) Codes and Standards Committee; Chris Sampl, Fairfax County, Office of the Fire Marshal; and Steve Shapiro, Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA).

Opposition: Ron Clements, Chesterfield County and VBCOA Admin and Existing Building Code Committees; and Gregg Fields, City of Alexandria.

Discussion:

Chris Sampl, on behalf of the proponent, provided an overview of the proposal and the associated floor modification. **Florin Moldovan** (DHCD staff) brought awareness to the group that DHCD staff has not had an opportunity to thoroughly review the floor modification due to the timing of submittal and invited stakeholders to review the floor modification thoroughly.

i. **Doug Banks** (Henrico County) asked how this proposal differs from the present requirement for non-required equipment.
ii. **Andrew Milliken** explained that the difference between this proposal and the previous proposal is that this proposal establishes if a building owner chooses to provide non-required equipment, the acceptance testing of that equipment is now not the responsibility of the locality.
iii. **Chris Sampl** added that the proposal provides an avenue for wireless emergency communication without having to get a code modification. The majority of the country already allows wireless communication.
iv. **Steve Shapiro** remarked that if the system is voluntary then there is no opposition.
v. **Ron Clements** indicated that voluntary systems are already allowed in the code and there is no need for code sections all over the code covering maintenance and testing requirements for voluntary systems.

vi. **Andrew Milliken** countered that the code as currently written does not simply allow voluntary emergency communications without adding responsibility to both the owner and the locality. This takes responsibility off the locality since it is voluntary.
vii. **Ron Clements** stipulated that if the locality is not providing equipment, you're exempt from this section. Electively installing it, does not undo Exception 6.
viii. **Shahriar Amiri** (Arlington County) questioned why this section is different from anything else that is voluntary as addressed in Chapter 1. If you provide stairs that are not required, they still must meet certain safety criteria.
ix. **Gregg Fields** mentioned that it is hard to grasp a voluntary code requirement where the voluntary requirement is not an exception to a mandatory requirement.

DHCD Staff Note:

This proposal conflicts with proposal B918.1-24, which was reviewed by stakeholders at the same GSW meeting and received a Non-Consensus recommendation. The excerpt from the January 6, 2026, meeting summary pertaining to B918.1-24 is provided below.

January 6, 2026, GSW Meeting Summary Excerpt

Support: Andrew Milliken, Stafford County Fire Marshal's Office and VFSB Codes and Standards Committee; Russell Furr, City of Alexandria Fire Marshal's Office; Gregg Fields, City of Alexandria; Dan Willham, Fairfax County and Virginia Building and Code Officials Association (VBCOA); and Shahriar Amiri, Arlington County.

Opposition: Steve Shapiro, Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA); and Ron Clements, Chesterfield County and VBCOA Admin and Existing Building Code Committees.

Discussion:

Chris Sampl, on behalf of the proponent, provided an overview of the proposal and the associated floor modification. **Florin Moldovan** (DHCD staff) brought awareness to the group that DHCD staff has not had an opportunity to thoroughly review the floor modification due to the timing of submittal and invited stakeholders to review the floor modification thoroughly.

i. **Gregg Fields** expressed relief that the proposal shifts the acceptance testing responsibility from the locality to the owner.
ii. **Dan Willham** drew attention to the fact that his locality has done building code modifications to allow wireless communication systems.

iii. **Steve Shapiro** explained that the prior code split the responsibility between the owner and the locality. Now the responsibility is all on the owner and it is a huge cost that includes fees and maintenance tests.

iv. **Chris Sampl** pointed to Exception 6 of Section 918.1 and clarified that the intent is for all jurisdictions to opt out if they don't want to have in-building communication requirements.

v. **Ron Clements** indicated that jurisdictions requiring these systems are doing so outside of the requirements of the current code, and that Exception 6, as modified, is not doing what is being claimed it is doing. **Ron C** elaborated the way the proposal is currently written does not get the locality out of a requirement.

B1006.3.4(1)-24

IBC: 1006.2.1, 1006.3.4, TABLE 1006.3.4(1), 1006.3.4.2 (New)

Proponents: Andrew Clark, representing Home Builders Association of Virginia (aclark@hbav.com)

2024 International Building Code

Revise as follows:

1006.2.1 Egress based on occupant load and common path of egress travel distance. Two *exits* or *exit access doorways* from any space shall be provided where the design *occupant load* or the *common path of egress* travel distance exceeds the values *listed* in Table 1006.2.1. The cumulative *occupant load* from adjacent rooms, areas or spaces shall be determined in accordance with Section 1004.2.

Exceptions:

1. The number of *exits* from foyers, lobbies, vestibules or similar spaces need not be based on cumulative *occupant loads* for areas discharging through such spaces, but the capacity of the *exits* from such spaces shall be based on applicable cumulative *occupant loads*.
2. *Care suites* in Group I-2 occupancies complying with Section 407.4.
3. Unoccupied mechanical rooms and *penthouses* are not required to comply with the common path of egress travel distance measurement.
4. Single exit six-story buildings complying with Section 1006.3.4.2.

1006.3.4 Single exits. A single *exit* or access to a single *exit* shall be permitted from any *story* or *occupiable roof* where one of the following conditions exists:

1. The *occupant load*, number of *dwelling units* and exit access travel distance do not exceed the values in Table 1006.3.4(1) or 1006.3.4(2).
2. Rooms, areas and spaces complying with Section 1006.2.1 with *exits* that discharge directly to the exterior at the *level of exit discharge*, are permitted to have one *exit* or access to a single *exit*.
3. Parking garages where vehicles are mechanically parked shall be permitted to have one *exit* or access to a single *exit*.
4. Group R-3 and R-4 occupancies shall be permitted to have one *exit* or access to a single *exit*.
5. Individual single-story or multistory *dwelling units* shall be permitted to have a single *exit* or access to a single *exit* from the *dwelling unit* provided that both of the following criteria are met:
   5.1. The *dwelling unit* complies with Section 1006.2.1 as a space with one *means of egress*.
   5.2. Either the exit from the *dwelling unit* discharges directly to the exterior at the *level of exit discharge*, or the *exit access* outside the *dwelling unit's* entrance door provides access to not less than two *approved* independent *exits*.

6. The building is not a *high-rise* building and contains only R-2 occupancies above the *level of exit discharge* and all of the following conditions are met:

6.1. There shall be no more than four dwelling units on any floor and the net floor area of each floor shall not exceed 4,000 square feet. Exception: Up to six dwelling units shall be permitted on any floor if the net floor area of each floor does not exceed 3,000 square feet.
6.2. The building construction shall be limited to types I, II-A, and IV. Exception: If the building does not exceed six stories *above grade plane*, construction type shall not be limited further than elsewhere in this code. For the purposes of this exception, *mezzanine* spaces shall be counted as additional stories.
6.3. A *corridor* shall separate each *dwelling unit* entry/exit door from the door to an interior exit stairway, including any related *exit passageway*, on each floor. *Dwelling unit* doors shall not open directly into an interior exit stairway. *Dwelling unit* doors are permitted to open directly into an exterior stairway.
6.4. An exterior stairway or interior exit stairway shall be provided. If an interior exit is provided, its doors must be automatic-closing, smoke-activated doors with clearly labeled hold-open devices in accordance with Section 716.2.6.6. 6.5. There shall be no more than 20 feet (6096 mm) of travel to the exit stairway from the entry/exit door of any dwelling unit. 6.6. Travel distance measured in accordance with Section 1017 shall not exceed 125 feet. 6.7. The building does not contain a *boarding house*. 6.8. Other occupancies are permitted in the same building provided they comply with all the requirements of this code. Other occupancies shall not communicate with the Group R occupancy portion of the building or with the single-exit stairway. Exception: Parking garages and occupied roofs accessory to the Group R occupancy are permitted to communicate with the exit stairway.
6.9. The exit serving the Group R occupancy shall not discharge through any other occupancy, including an accessory parking garage. 6.10. There shall be no openings within 10 feet (3048 mm) of unprotected openings into the stairway other than required exit doors having a one-hour fire-resistance rating. 6.11. The emergency power illumination requirements in section 1008.3 shall be provided regardless of there being only one means of egress under this section.

TABLE 1006.3.4(1) STORIES AND OCCUPIABLE ROOFS WITH ONE EXIT OR ACCESS TO ONE EXIT FOR R-2 OCCUPANCIES

STORY	OCCUPANCY	MAXIMUM NUMBER OF DWELLING UNITS	MAXIMUM EXIT ACCESS TRAVEL DISTANCE
Basement, first, second ~~or~~ third, forth, fifth, sixth story above grade plane and occupiable roofs over the first, ~~or~~ second, third, forth, or fifth story above grade plane	R-2[a, b, c, d]	4 dwelling units	125 feet
~~Fourth~~ Seventh story above grade plane and higher	NP	NA	NA

For SI: 1 foot = 304.8 mm.

NP = Not Permitted.

NA = Not Applicable.

a. Buildings classified as Group R-2 equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2 and provided with emergency escape and rescue openings in accordance with Section 1031.

b. This table is used for Group R-2 occupancies consisting of dwelling units. For Group R-2 occupancies consisting of sleeping units, use Table 1006.3.4(2).

c. This table is for occupiable roofs accessed through and serving individual dwelling units in Group R-2 occupancies. For Group R-2 occupancies with occupiable roofs that are not accessed through and serving individual units, use Table 1006.3.4(2).

d. 6-story buildings and 5-story buildings with an occupiable roof above the fith story shall also comply with Section 1006.3.4.2.

Add new text as follows:

1006.3.4.2 Single exit six-story buildings with Group R-2 dwelling units. Six-story buildings with a single exit for Group R-2 dwelling units shall comply with Table 1006.3.4(1) and all of the following:

1. The net floor area of each floor shall not exceed 4,000 square feet (418.5 m).

2. Doors opening into the exit stairway must open in the direction of egress travel.

3. Electrical receptacles shall be prohibited in exit stairway.

4. In addition to the requirements for emergency escape and rescue openings in Section 1031.2, sleeping rooms on the fourth story above grade plane shall have not fewer than one emergency escape and rescue opening in accordance with Section 1031.

5. For interior exit stairways:

a. Openings to the interior exit stairway enclosure shall be limited to those required for exit access into the enclosure from normally occupied spaces, those required for egress from the enclosure, and openings to the exterior. Elevators shall not open into the interior exit stairway enclosure. Dwelling unit doors shall not open into the interior exit stairway enclosure.

b. A manual fire alarm system and automatic smoke detection system that activates the occupant notification system in accordance with Section 907.5 shall be provided. Smoke detectors shall be located in common spaces outside of dwelling units, including but not limited to gathering areas, laundry rooms, mechanical equipment rooms, storage rooms, interior corridors, interior exit stairways, and exit passageways.

c. Regardless of the stairway construction type, automatic sprinkler locations in interior exit stairways shall comply with the requirements of NFPA 13 for combustible stairways.

6. Exterior exit stairways must be constructed of noncombustible materials or fire-retardant-treated wood framing and sheathing complying with Section 2303.2.

7. The emergency power illumination requirements in section 1008.3 shall be provided regardless of there being only one means of egress under this section.

Reason Statement: A proposal to allow six-story residential buildings to be served by a single exit aims to help increase housing supply by making it more feasible to design and build mid-rise multifamily projects, especially on constrained urban infill sites where traditional two-stair configurations are impractical or cost-prohibitive. By modernizing egress requirements, this code change could enable more efficient use of available land and facilitate the delivery of additional housing units in areas facing housing shortages.This proposal creates a new pathway under the IBC to permit single-stair, six-story residential buildings, expanding upon the four-story single-exit proposal (B1006.3.4-24) marked Consensus Approval from the general stakeholder workgroup earlier this year. It incorporates the same safety measures and design safeguards developed and supported by fire-services and other stakeholder groups, including enhanced fire protection, travel distance limits, emergency lighting, and restricted floor area and unit counts. These measures maintain an equivalent level of life safety while allowing more flexible, space-efficient, and attainable multifamily design.
Building on those provisions, this proposal adds further protections appropriate for six-story construction, ensuring equal or greater levels of occupant safety through strengthened fire-resistance, detection, and egress requirements.This draft has not yet been presented to fire service or other stakeholder groups for review. We welcome their feedback and are committed to working to refine the proposal and reach common ground on both safety and design objectives.

Cost Impact: The code change proposal will not increase or decrease the cost The cost impact of this proposal has not been definitively established; however, its added design flexibility can unlock new development opportunities on constrained or irregular infill sites. By permitting a single-stair configuration under clearly defined safety provisions, the change allows for more efficient building layouts, recovers valuable floor area that would otherwise be dedicated to a second stair and corridor, and creates additional options for family-sized units or shared amenities. Studies suggest this flexibility can reduce construction costs by 6% to 13% in typical mid-rise projects and support the creation of additional housing units in markets where land and development costs are high, thereby helping address local housing shortages.

B1006.3.4(1)-24 – Staff Summary

Proponent: Andrew Clark, representing Home Builders Association of Virginia

Brief Description: Increases the maximum number of stories allowed for Group R-2 occupancies with a single exit, from three stories to six stories.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting — 01/06/2026

Support: Richard Hankins, Partnership for Smarter Growth.

Opposition: Dan Willham, Fairfax County and Virginia Building and Code Officials Association (VBCOA); Russell Furr, City of Alexandria Fire Marshal's Office; and Andrew Milliken, Stafford County Fire Marshal's Office and Virginia Fire Services Board (VFSB) Codes and Standards Committee.

Discussion:

Andrew Clark provided an overview of the proposal.
Jeff Brown (DHCD staff) announced to the stakeholders that this proposal is similar to proposal B1006.3.4-24, which was already heard at a previous General Stakeholder Meeting. When there are similar proposals, regardless of whether it is Consensus for Approval or Non-Consensus, DHCD staff will flag those for the Board.

i. **Andrew Milliken** asked if the proposal was submitted by the Home Builders Association.
ii. **Andrew Clark** confirmed that it was.
iii. **Richard Hankins** stated that single stair reform is a valuable tool to solve our affordable housing issue. There was a study done in Minnesota that found that an eight-story single stair building with 6,000 square feet per floor had a lower fire risk than an eight-story building that has two staircases.
iv. **Dan Willham** expressed opposition and recommended relying on what has been approved at the national level and with the study group that Virginia put together. The additional provisions that this proposal provides do not appear to be equivalent to providing compensation for the additional height and occupant load for a single exit.
v. **Andrew Milliken** expressed frustration that what is in this proposal was not included in the discussions that were had and provided thirteen specific reasons why this proposal is not good for Virginia.

1. Section 1006.2.1 is for exits from rooms or spaces on a floor, not exits from a floor. The addition of item four is shown as essentially not appropriate for that section.
2. Section 1006.2.1 item four only applies to six story buildings and not four and five story buildings and skips all the new requirements in Section 1006.3.4 and Table 1006.3.4(1).
3. Proposed Section 1006.3.4(6) would allow single exit stairs in buildings more than six stories, if they are not high rise, which doesn't match the scope indicated in the Reason Statement.
4. Proposed Section 1006.3.4 Item 6.1 allows up to six dwelling units per floor if the floor area is 3000 square feet or less, which seems to conflict with the limitations proposed in Table 1006.3.1 which limits single exit stair buildings to a maximum of four units per floor.
5. Proposed Section 1006.3.4 Item 6.2 has an exception that eliminates any added construction type benefit to this section that it's intended to provide, since an R-2 over six stories already must be of a Type I or Type IV construction per Section 504.4.
6. Proposed Section 1006.3.4 Item 6.10 does not make any sense as written, and is also probably not accurate for the doors into stairs serving four more stories, since the stair enclosure is required in two hours, not one hour, this proposal has at least two, if not three, sets of new requirements for single exit stairs that seem to overlap and conflict and would be extremely confusing as proposed.
7. Proposed Table 1006.3.4 Item 1, Note a, would now apply to four, five, and six story buildings, but Section 1031 reference for emergency escape and rescue openings only applies to buildings of one to three stories.
8. Proposed Table 1006.3.4 Item 1, Note d, seems to indicate that four and five story single exit stair buildings do not have to comply with Section 1006.3.4.2.
9. Proposed title to Section 1006.3.4.2 indicates that it is only applicable to six-story buildings. So, it sounds like it's not in ten, four, five or seven story buildings.
10. Proposed Section 1006.3.4.2 Item 4 would only apply to four stories but would not apply to the fifth and sixth floor.
11. The Reason Statement says this proposal incorporates the same safety measures and design standard safeguards developed and supported by the fire service and other stakeholders, but the proposal does not apply them equivalently as compared to the consensus proposal.
12. The Reason Statement indicates that the proposal provides an equivalent level of safety but provides no basis as to how it is in any way equivalent to the current or even the consensus proposal.

13. The Reason Statement further indicates that this proposal adds additional protection beyond those in the consensus proposal that are appropriate for six story construction and ensures an equal or greater level of occupant safety through strengthened fire-resistance, detection, and egress requirements, but again, doesn't specifically indicate where those are located or how they are accomplished in this proposal.

vi. **Andrew Clark** questioned what requirements are needed to add the two additional stories from the four-story proposal that would satisfy fire services.

DHCD Staff Notes:

This proposal conflicts with Proposal B1006.3.4-24. That proposal was reviewed by stakeholders during the second GSW meeting on October 3, 2025, and received a Consensus Approval recommendation.

The initial draft of Proposal B1006.3.4-24 underwent detailed review by the Single Exit Stair Study Group (SG) on June 24, 2025.[1] The proponent subsequently revised the proposal in response to issues identified at the SG meeting, and the final version received Consensus Approval at the October GSW meeting.

[1] See Book 2, Tab 10 for the Single Exit Stair Study Group meeting summary.

B1110.4-24

IBC: 1110.4, 1110.4.1, 1110.4.2, 1110.4.3, 1110.4.4, 1110.4.5 (New), 1110.4.6 (New), (New)

Proponents: Kim Kirkwood and Monika Thrower, representing Changing Spaces Virginia

2024 International Building Code

1110.4 Adult changing stations.. Where provided, adult changing stations shall be accessible. Where required, adult changing stations shall be accessible and shall comply with Sections 1110.4.1 through 1110.4.4.

Revise as follows:

1110.4.1 Where required. Not fewer than one adult changing station shall be provided in the following locations:

1. In assembly and mercantile occupancies, where family or assisted-use toilet or bathing rooms are required to comply with Section 1110.2.1. In mercantile occupancies where an aggregate of six or more water closets is required or where eight or more water closets is provided for public use, an adult changing station shall be provided. Where adult changing stations are provided in separate sex toilet rooms, an adult changing station shall be provided in each toilet room or in a family or assisted-use toilet room complying with Section 1110.2.1.2.
2. In Group B occupancies providing educational *facilities* for students above the 12th grade, where an aggregate of 12 or more male and female water closets are required to serve the classrooms and lecture halls.
3. In Group E ~~occupancies, where~~ occupancies:

   a. Where a room or space used for assembly purposes requires an aggregate of six or more male and female water closets for that room or space.

   b. Where specialized learning spaces are provided and designed for students with disabilities who require assistance in toileting is provided and is served by a toilet room primarily for the occupants of such learning spaces.
4. In highway rest stops and highway service plazas.
5. State park campgrounds provided with plumbing and electricity at toileting locations.
6. State park visitor centers provided with plumbing and electricity at toileting locations.
7. In hospitals and ambulatory care facilities, where an aggregate of six or more male and female water closets are required to serve public visitors and outpatient visitors.

1110.4.2 Room. Adult changing stations shall be located in toilet rooms that include only one water closet and only one lavatory. The assistive tables shall comply with IAPMO Z1390. Fixtures located in such rooms shall be included in determining the number of fixtures provided in an occupancy. The occupants shall have access to the required adult changing station at all times that the associated occupancy is occupied.

Exception: Adult changing stations shall be permitted to be located in family or assisted toilet rooms required in Section 1110.2.1.

1110.4.3 Prohibited location.. The *accessible route* from separate-sex toilet or bathing rooms to an accessible adult changing station shall not require travel through security checkpoints.

1110.4.4 Travel distance.. The adult changing station shall be located on an *accessible route* such that a *person* is not more than two *stories* above or below the *story* with the adult changing station and the path of travel to such *facility* shall not exceed 2,000 feet (609.6 m).

Add new text as follows:

1110.4.5 Directional signage. The locations of the adult changing stations are to be identified on any directional graphic of the facility

used to orient the public visitor.

1110.4.6 Room designation signage. Signs identifying toilet rooms and bathing rooms shall indicate when adult changing tables are provided in that room.

Revise as follows:

Chapter 35. Add new standard promulgator and standard, as follows:

IAPMO International Association of Plumbing and Mechanical Officials

4755 E. Philadelphia St.; Ontario, CA 91761

IAPMO Z1390-2024e1

Reason Statement: For Virginia to adopt building code regarding adult changing stations so that new buildings will include an adult changing station. The scope and specifications we would like to adopt in VA are the 2024 IBS I-codes, Chapter 11, Accessibility, Sections 110.4 - 110.4.4, and ICC A117.1 2017 with Supplement 1: Standard for Accessible and Useable Buildings and Facilities, section 613: Adult Changing Stations. This supplement provides a pathway to compliance with accessible adult changing stations in the 2024 I-codes.

This is important because, according to the ICC Adult Changing Facilities work group: "Limiting access to those who need adult changing stations decreases the community size dramatically. Nationally, the Centers for Disease Control and Prevention (CDC) reports 61 Million adults (26% of the US population) have some form of disability, with 24.1% affected in the areas of mobility, independent living, and selfcare. Further, each of those folks need assistance, and likely travel with additional family members. Once this population is taken out of the community, businesses are also losing a large potential of support and income. Providing our citizens more opportunities to participate in the community and patronize local establishments strengthens communities, allowing all family members to engage or travel together as one family nucleus. Currently many families have to make the choice to participate in activities outside of the home with only a portion of their family.

Individually, families from many states are pushing for the adult changing facilities. A national campaign, Changing Spaces, has been activated, with chapters in at least 10 states, advocating for height adjustable changing tables to be required in public places.
Many states are working on or have already enacted legislation that will require adult changing stations in their states. Accepting this proposal will show wide-spread acceptance of the need along with a consistent set of standards across the country for users to rely on.
We are all part of an aging population, and the elderly still want to be able to attend family gatherings and travel in a car to be with relatives. These adult changing facilities would be valued not only by families with adult disabled children but also be aging adult family members.

Without appropriate changing facilities, families cannot travel more than 30-40 miles from home. Additionally, trips that involve more than a few hours of time are also a risk.
As a result, vacations, trips to zoos, aquariums, museums, concerts, and similar events are eliminated.

The addition of adult changing tables will present a tremendous change in the quality of life for so many people who were unable to get out and participate in many activities before due to the lack of adequate facilities.

Cost Impact: The code change proposal will not increase or decrease the cost
Although building cost will be slightly higher due to installing the adult changing table, which also requires a larger family bathroom, businesses will profit from an increased customer base. Our state will experience increased tourism and travel once people with disabilities and medical conditions can stop at rest stops to use the adult changing table. Businesses will increase revenue by accommodating an underserved population that has disposable income.

According to an AIR report, (https://www.air.org/resource/report/hidden-market-purchasing-power-working-age-adults-disabilities) working-age individuals with disabilities wield substantial economic clout. They have access to approximately $504 billion annually; comparable to major consumer segments such as African Americans ($501 billion) and Hispanics ($582 billion).
The discretionary income of individuals with disabilities stands at approximately $21 billion, surpassing the combined discretionary income of African American and Hispanic populations.

Attached Files

- **Reason Statement and Cost Impact.pdf**
  https://va.cdpaccess.com/proposal/1545/2255/files/download/1018/

17 APRIL 2018 | REPORT

A Hidden Market: The Purchasing Power of Working-Age Adults With Disabilities

Michelle Yin, Dahlia Shaewitz, Cynthia Overton, and Deeza-Mae Smith

People with disabilities provide a twofold opportunity for business and industry. First, businesses benefit from hiring people with disabilities by increasing the diversity of their labor force, inspiring innovation, and improving productivity; they benefit from an increase in favorable public perception. Second, people with disabilities also represent a vast consumer market for high-quality services and products.



This report examines the significant and growing economic power of the disability market through the lens of disposable and discretionary income, and provides information to help motivate businesses to enter this market. (*Disposable income* is money available after taxes to spend on essential living expenses; *discretionary income* is money available for nonessential items after taxes and basic living expenses have been met.) The report also discusses implications for businesses, next steps to aid in accessing this market, and specific examples of companies in the United States that have experienced strategic benefits from employing, marketing to, and developing specific products for people with disabilities.

Key Findings

- The total after-tax disposable income for working-age people with disabilities is about $490 billion, which is similar to that of other significant market segments, such as African Americans ($501 billion) and Hispanics ($582 billion).
- Discretionary income for working-age people with disabilities is about $21 billion, which is greater than that of the African-American and Hispanic market segments combined.
- Disposable and discretionary income varies by disability type and by state—information that can help business leaders as they make plans to access the disability market.

People with disabilities are not a solitary market; they are surrounded by family members and friends who also recognize the value in products and services that accommodate all people in society.

The Spending Power of Working-age Adults with Disabilities

AIR report explores a hidden market of consumers and finds that working-age adults with disabilities are a large market for businesses in the U.S.

Who Are People With Disabilities?



1 in 5
U.S. Adults, or 64 million people, have a disability





Of those, **35%**, or 22 million, are of prime working-age (ages 16–64)

Measuring Spending Power Through Disposable and Discretionary Income

Businesses and market researchers often estimate the disposable and discretionary income of a group to assess market size, growth, and population characteristics.

What is Disposable Income?

Money available after taxes to spend on essential living expenses





What is Discretionary Income?

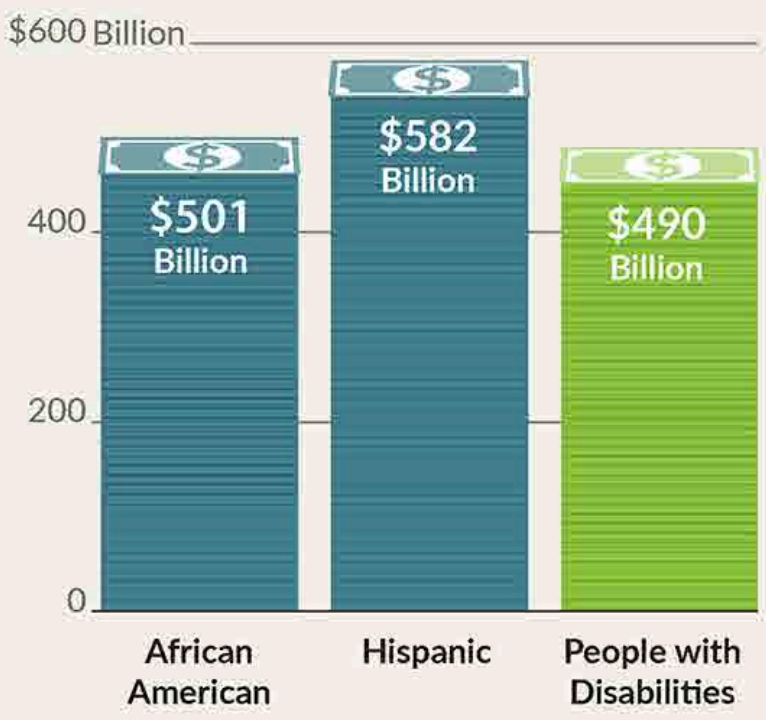
Money available after taxes and basic living expenses have been met to spend on luxury or nonessential items



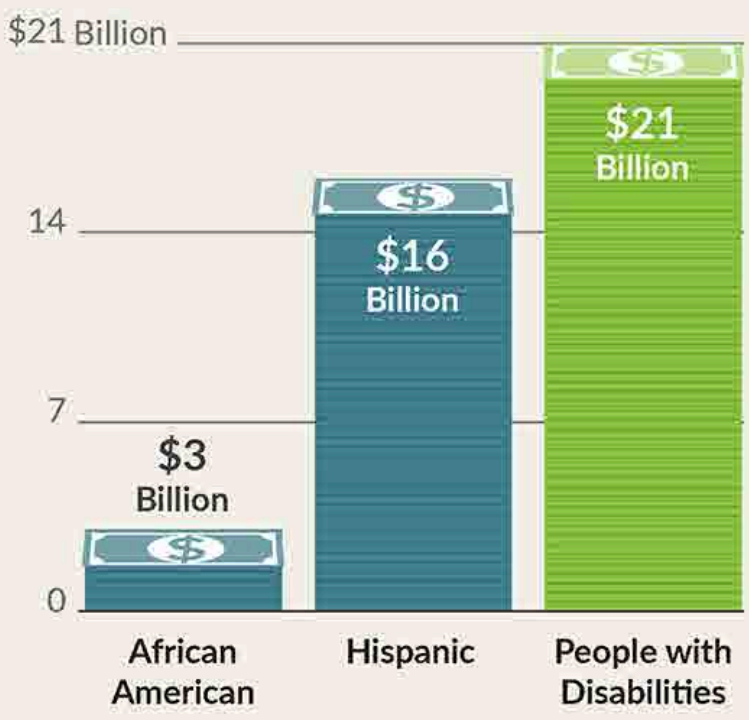
The Spending Power of People with Disabilities Compared to Those Without Disabilities, Including Other Significant Market Groups

While working-age people with disabilities have significantly lower disposable and discretionary incomes than people without disabilities, the report finds they still have significant spending power compared to other similarly sized market segments, such as African Americans and Hispanics.

Total disposable income by market segment



Total discretionary income by market segment





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Garima Siwach
Principal Economist
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Reason Statement and Cost Impact

Reason Statement:

For Virginia to adopt building code regarding adult changing stations so that new buildings will install an adult changing table according to the scope and specifications of E142-21 and ICC/ANSI A117.1. This is important because, according to the ICC Adult Changing Facilities work group:
“Limiting access to those who need adult changing stations decreases the community size dramatically. Nationally, the Centers for Disease Control and Prevention (CDC) reports 61 million adults (26% of the US population**)** have some form of disability, with 24.1% affected in the areas of mobility, independent living, and selfcare. Further, each of those individuals need assistance, and likely travel with additional family members. Once this population is taken out of the community, businesses are also losing a large potential of support and income. Providing our citizens more opportunities to participate in the community and patronize local establishments strengthens communities, allowing all family members to engage or travel together as one family nucleus. Currently many families have to make the choice to participate in activities outside of the home with only a portion of their family.

Individually, families from many states are pushing for the adult changing facilities. A national campaign, Changing Spaces, has been activated, with chapters in at least 10 states, advocating for height adjustable changing tables to be required in public places. Many states are working on or have already enacted legislation that will require adult changing stations in their states. Accepting this proposal will show wide-spread acceptance of the need along with a consistent set of standards across the country for users to rely on. We are all part of an aging population, and the elderly still want to be able to attend family gatherings and travel in a car to be with relatives. These adult changing facilities would be valued not only by families with adult disabled children but also by aging adult family members. Without appropriate changing facilities, families cannot travel more than 30-40 miles from home. Additionally, trips that involve more than a few hours of time are also a risk. As a result, vacations, trips to zoos, aquariums, museums, concerts, and similar events are eliminated before, due to the lack of adequate facilities.

Cost Impact

Cost Impact: The code change proposal will not increase or decrease the cost
Although building cost will be slightly higher due to installing the adult changing table, which also requires a larger family bathroom, businesses will profit from an increased customer base. Our state will experience increased tourism and travel once people with disabilities and medical conditions can stop at rest stops to use the adult changing table. Businesses will increase revenue by accommodating an underserved population that has disposable income.

According to an AIR report, (https://www.air.org/resource/report/hidden-market-purchasing-power-working-age-adults-disabilities) working-age individuals with disabilities wield substantial economic clout. They have

access to approximately $504 billion annually; comparable to major consumer segments such as African Americans ($501 billion) and Hispanics ($582 billion).
The discretionary income of individuals with disabilities stands at approximately $21 billion, surpassing the combined discretionary income of African American and Hispanic populations.

Public Comments (PCH) for: B1110.4-24

Discussion by Monika Thrower

Nov 2, 2025 18:01 UTC

We would like to request the bellow additional code language to be added to the Adult Changing Station proposal.

A202.10.8.5 Directional Signage. The locations of the adult changing stations are to be identified on any directional graphic of the facility used to orient the public visitor.

A202.10.8.6 Room designation signage. Signs identifying toilet rooms and bathing rooms shall indicate when adult changing tables are provided in that room.

Attachments: http://localhost/proposal/1545/discuss/222/file/download/1035/Additional%20code%20language.pdf

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Proposal # 1545

Outlook

PUBLIC COMMENT for B11.10.4,

From Yehuda Katz <yehuda@ymkatz.net>
Date Sat 1/17/2026 8:39 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:
I am writing in support of proposal B11.10.4. which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will dramatically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restroom needs while away from home. Currently, countless children and adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or being changed in unsanitary, unsafe, and undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because when I go to Virginia for work or Boy Scout events, it is hard to find a place to change older kids with special needs who wear diapers.

Sincerely,
- Y

Outlook

PUBLIC COMMENT for B11.10.4

From Kellie Kouri <kelliekouri@gmail.com>
Date Fri 1/16/2026 10:26 AM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B11.10.4. which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will dramatically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restroom needs while away from home. Currently, countless children and adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or being changed in unsanitary, unsafe, and undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because my dear friend has devoted her entire life caring for her handicapped son and this is a way to ease some of the burden.

Sincerely,

Kellie Kouri

Outlook

Public comment for code change proposal B11.10.4

From Jessica Clark <jessclark141819@gmail.com>
Date Fri 1/16/2026 8:22 AM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:
I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their

vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because I change my 11 year old daughter in the back of my vehicle and she is uncomfortable, exposed, and as she enters puberty it is a growing concern for sanitation and safety for her health mental and physical as she is subjected to public embarrassment. This doesn't seem to coincide with community inclusion or support. We take family outings and timing for changing our incontinent daughter very seriously and try to find secluded areas of restrooms, parking lots, or parks to change her as she is not small and needs the space.

Sincerely,
Jessica Clark

And my daughter. Annabelle.



Outlook

Public comment for code change proposal B11.10.4

From Christine <christineowens83@gmail.com>
Date Thu 1/15/2026 6:07 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B11.10.4. which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will dramatically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restroom needs while away from home. Currently, countless children and adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or being changed in unsanitary, unsafe, and undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because I have a child with autism, who is able to use the restroom, but if he weren't, then we would need to use this option, which is why I think it's so important.

Sincerely,

- Christine Owens

Outlook

PUBLIC COMMENT for B11.10.4

From Laura Michaels <lauramicha@gmail.com>
Date Thu 1/15/2026 5:00 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of Housing and Community Development:
I am writing in strong support of proposal B11.10.4, which will require Adult Changing Stations in new buildings of certain types in Virginia. Approving this proposal is a meaningful step toward ensuring that our public spaces reflect the principles of Universal Design—designing environments that anticipate and support the full range of human needs.
Universal Design has advanced significantly in recent years, and this proposal continues that progress. Adult Changing Stations provide a safe, private, and dignified place for people with disabilities to address their restroom needs while away from home. Without them, countless children and adults who have disabilities or medical conditions are left with no appropriate place to change undergarments or clothing once they have outgrown baby changing tables. As a result, many individuals become isolated at home or are forced into unsafe, unsanitary, and undignified situations—such as being changed on the floor of a public restroom, on a picnic blanket outside, or in the back of a vehicle.
Installing Adult Changing Stations within family restrooms is not simply a convenience; it is an essential component of creating inclusive, accessible communities. When we design with Universal Design principles in mind, we ensure that all people—regardless of disability, age, or medical need—can participate fully in community life.
This is important to me personally because I support friends in my community who have accessibility needs, and I see firsthand how thoughtful, inclusive design can open doors—literally and figuratively. When our public spaces include features like Adult Changing Stations, it allows the people I care about to participate fully in community life without barriers, discomfort, or indignity. These improvements reflect the kind of Virginia I want to live in: one where every person is welcomed, supported, and able to engage in daily life with independence and dignity.
Sincerely,
Laura Michaels

Laura Michaels, M.Ed.
EdTech Consultant
vaeducatorlcm@gmail.com
lauramicha@gmail.com
Google Voice: **(804) 214-6467**
bit.ly/Eclec-Tech



CERTIFIED SWaM Small, Women and Minority-Owned
Supplier Diversity Strengthens the Commonwealth
by the Virginia Department of Small Business & Supplier Diversity

Outlook

Public comment for Code change Proposal B11.10.4

From Kelly Brooks <kthbrooks@gmail.com>
Date Thu 1/15/2026 12:43 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

I am writing in support of proposal B1 1.10.4. which will make adult changing stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult who have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because my daughter with cerebral palsy is now 16 and cannot be

changed on a baby changing table or in public venues. It limits our ability to attend community events as a family because there is nowhere to change her when the need arises. Having easy access to an adult changing station would vastly improve her and our family's quality of life and preserve her dignity and privacy.

Thanks for your consideration.

Kelly Brooks
Henrico, VA
804.310.5656

Outlook

Public comment for code change proposal B11.10.4

From CATHERINE PARR <parrcatmp2000@aol.com>
Date Thu 1/15/2026 11:13 AM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of Housing and Community Development,

I am writing in strong support of proposal B11.10.4, which would require Adult Changing Stations in certain new buildings in Virginia.

Approving this proposal would significantly improve the quality of life for many people with disabilities and medical conditions by ensuring access to a safe, private, and dignified place to address personal care needs while away from home. Currently, many children and adults with disabilities have no appropriate place to change undergarments or clothing once they outgrow infant changing tables. As a result, individuals and their families are often forced into unsafe, unsanitary, and undignified situations — such as changing on the floor of a public restroom, on the ground outdoors, or inside a vehicle.

Because of these barriers, many people with disabilities become isolated and avoid participating fully in community life. Adult Changing Stations located in family or companion restrooms are essential to true accessibility and inclusion, allowing people of all ages and abilities to live, work, and engage in their communities with dignity.

This issue is deeply personal to me. As a person with a physical disability and a wheelchair user, I am also an active disability advocate who regularly works to raise awareness about accessibility, independent living, and inclusion for people with disabilities. Through my advocacy, I have seen firsthand how the lack of appropriate restroom accommodations affects individuals and families across Virginia. Adult Changing Stations are not a luxury — they are a necessary accessibility feature that supports independence, health, and equal access for countless Virginians.

I respectfully urge you to approve proposal B11.10.4 and take this important step toward making Virginia more inclusive and accessible for everyone.

Sincerely,

Cathy Parr



Ms wheelchair Virginia 2021-2024
Sent from my iPhone

Outlook

Public comment for B11.10.4

From Katie Moore <kmoore732010@gmail.com>
Date Thu 1/22/2026 8:32 AM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B11.10.4. which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will dramatically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restroom needs while away from home. Currently, countless children and adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or being changed in unsanitary, unsafe, and undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because I have a severely disabled daughter who will be in diapers for life. I cannot even begin to express to you how difficult and dehumanizing it is to change my daughter on dirty, disgusting bathroom floors or change her outside in my car, where her private parts are exposed to anybody who walks by. Not only is it absolutely disgusting to change people, like my daughter on floors, but it is humiliating for them and extremely difficult for caregivers to change diapers in these conditions.
People, like my daughter, deserve a bathroom option that protects their privacy, dignity, humanity and safety.

Sincerely,
Kathryn spinks


HAPPY
BIRTHDAY
HAPPY
BIRTHDAY
JOLENE!

Outlook

Public comment for code change proposal B11.10.4

From Courtney Neilson Carlson <neilson.courtney@gmail.com>
Date Tue 1/27/2026 10:10 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of Housing and Community Development:

I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia.

My son is eight and no longer fits on the small changing tables that are located in most public bathrooms. As a result, I've had to change his diaper on the floor of public bathrooms. It's awful and unsanitary. He deserves to be changed in a dignified, safe, and clean way (just like everyone else). It's hard to be out in the community and do things as a family due to the lack of adult/changing tables in the state. This lack of accessibility has lead us and other families like ours to become isolated. We would love to be able to be part of this society.

By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

Please help make this world a safer and more accessible place, so that we can all enjoy this world together!

Sincerely,

Courtney

Outlook

Public comment for code change proposal B11.10.4

From Katey Leatham <kateyleatham@gmail.com>
Date Thu 1/29/2026 10:44 AM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B11.10.4. which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will dramatically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restroom needs while away from home. Currently, countless children and adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or being changed in unsanitary, unsafe, and undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because a dear friend of mine is in wheelchair and deals with this challenge on a regular basis. Everyone deserves access to public restrooms that work for their dignity.

Sincerely,

Katey Leatham
kateyleatham@gmail.com
302.932.4222 cell

Outlook

Public comment for code change proposal B11.10.4

From Patsy Hubbard <sphubbard@cox.net>
Date Mon 3/23/2026 3:54 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To: The Virginia Board of housing and community development

I am writing in support of proposal B1 1.10.4. which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, I agree with the need to drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because these individuals need everyone's attention and empathy to ensure they can enjoy being out in the world.

Sincerely,

Patsy Hubbard
Fairfax, VA

Outlook

Public comment for code change proposal B11.10.4

From Cameron Parkins <cgparkins@gmail.com>
Date Mon 3/23/2026 9:35 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because my friend's son, Wes, has physical limitations that lead him to need the support of a child/adult sized changing table in order to exist in public. It's important to Wes and to his family. And so, it's important to me.

Sincerely,
Cameron

Outlook

Public comment for code change proposal B11.10.4

From Catherine Cribbs <cribbscatherine@gmail.com>
Date Mon 3/23/2026 9:57 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B1 1.10.4, which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home.

Currently, countless children and adults that have a disability or medical condition have nowhere to change undergarments or clothing while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing Stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because I have several people in my life who would benefit from these stations. And as a first-time mom to a 20-month-old, I learned quickly how vital it is to have a sanitary changing station available when I need one. But my child will outgrow the need for this, and many people do not. They are just as deserving of dignified changing spaces as the rest of us.

Sincerely,
Catherine Cribbs

Outlook

Public comment for code change proposal B11.10.4

From Milly <espinozamilagros284@gmail.com>
Date Mon 3/23/2026 10:13 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:
I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because…

Sincerely,



Milagros Espinoza
Sent from my iPhone

Outlook

Public comment for code change proposal B11.10.4

From Jill Lemon <jill@thesbx.co>
Date Mon 3/23/2026 10:51 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B1 1.10.4., which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home.

Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is personally important to me because our friends are often homebound and desperately deserve to share our beautiful world with their beautiful son, Wes. Please make this possible by providing more adult changing stations in Virginia!

Very sincerely,

Jill Lemon
Partner | Sandbox
(804) 317-4399
www.workhardplaynice.com

Outlook

Public comment for code change proposal B11.10.4

From Kendall Beaver <kcbeaver17@gmail.com>
Date Tue 3/24/2026 8:11 AM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because I have a family member it directly impacts.

Sincerely,
Kendall Wille

Outlook

Public Comment for Code

From Nate Wille <natewille24@gmail.com>
Date Tue 3/24/2026 8:14 AM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because I had a family member that it directly impacts.

Sincerely,
Nathan Wille

Outlook

Public comment for code change proposal B11.10.4

From Lucy Wysong <lmartinwysong47@gmail.com>
Date Tue 3/24/2026 9:48 AM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

I support this code change to give everyone the privacy they need. Let's start doing nice things to help folks!
Lucy Wysong
1143 Stokes Station Road
Goochland VA
Sent from my iPhone

Outlook

Public comment for code change proposal B11.10.4

From Josh C <jcarncro@hotmail.com>
Date Tue 3/24/2026 11:12 AM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

1 attachment (150 KB)
IMG_5488.jpeg;

To the Virginia Board of housing and community development:

I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because my young family member lives with a condition that requires him to use a wheel chair and significantly affects his movement and other motor skills. It is heartbreaking hearing how upset he becomes while he has to make due with the facilities available to him in public spaces. He is now old enough to feel the embarrassment and know he's the center of attention for the wrong reasons. Life is hard enough for him, this is a simple solution and one that doesn't take a lot of effort on our part to help with. A change like this would make a big difference in his everyday life and markedly improve his quality of life.

Sincerely,

Josh Carncross

Sent from my iPhone as all my carrier pigeons have died.

Outlook

Public comment for code change proposal B11.10.4

From Abigail Cinco <anjcinco@icloud.com>
Date Tue 3/24/2026 8:10 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:
I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.
This is important to me because everyone should have the right to feel comfortable in a public spaces, having this will make everyone feel included.

Sincerely,
Abby Cinco

Outlook

Public comment for code change proposal B11.10.4

From Alycea Sparks <alyceasparks8@icloud.com>
Date Tue 3/24/2026 6:48 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:
I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because there was once a time in my life I never thought the restroom could be an issue until I had my son. I always seen signs for handicap and accessibility until I realized that disabilities come in many forms and not everything will work just by adding wider spaces and handle bars. Once he grows out of the infant size changing table I will either have to change him on the dirty bathroom floors or out in the parking lot in my car which is degrading. We need better access for all!

Sincerely,
Alycea Branin

Sent from my iPhone

Outlook

Public comment for code change proposal B11.10.4

From Bret Walker <walkerbc@vcu.edu>
Date Tue 3/24/2026 8:06 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because I have worked with adults with disabilities within my career and have seen first hand how this would be beneficial to these individuals.

Best,

Bret Walker, OTS
Virginia Commonwealth University
OTD Class of 2028
he/him

Outlook

Public Comment for Code Change Proposal B11.10.4

From Riley Smith <smithrc11@vcu.edu>
Date Tue 3/24/2026 8:11 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development,

I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because I have seen firsthand how detrimental it is for individuals not to have universal access to resources for health maintenance.

Best,

Riley Smith, OTS
VCU OTD Class of 2028
smithrc11@vcu.edu
(804) 836-3442

Outlook

Public comment for code change proposal B11.10.4

From Summer McKinney <mckinneysr@vcu.edu>
Date Tue 3/24/2026 8:16 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because as an occupational therapy student I believe safety and accessibility should be a top priority for our citizens and by providing these changing tables many lives will be changed and impacted for the better.

Sincerely,
Summer McKinney

Outlook

Public comment for code change proposal B11.10.4

From Summer McKinney <mckinneysr@vcu.edu>
Date Tue 3/24/2026 8:16 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because as an occupational therapy student I believe safety and accessibility should be a top priority for our citizens and by providing these changing tables many lives will be changed and impacted for the better.

Sincerely,
Summer McKinney

Outlook

Public comment for code change proposal B11.10.4

From Jacqui Kazmierczak <jacquikaz@yahoo.com>
Date Tue 3/24/2026 8:17 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:
I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.
This is important to me as an Occupational Therapy student because I have seen the lack of accessibility in many public areas. This prevents people with disabilities or medical conditions from being able to go out socialize because they will not be able to properly change clothing. I strongly urge you to support this code change to help make a difference in individuals lives.
Sincerely,
Jacqui Kazmierczak, OTS

Outlook

Public comment for code change proposal B11.10.4

From Laura Dillard <dillardlh@vcu.edu>
Date Tue 3/24/2026 8:19 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:
I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

Sincerely,
Laura Dillard, OTS
VCU OTD Class of 2028

Outlook

Public comment for code change proposal B11.10.4

From Jordan Wattis <jawattis@gmail.com>
Date Tue 3/24/2026 8:34 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:
I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This issue is personally important to me because, as someone entering a helping profession, I believe dignity and access should extend across the lifespan. The lack of adult changing tables directly limits individuals' ability to participate in meaningful activities and engage fully in their communities.

Sincerely,
Jordan Wattis, OTS


VCU College of Health Professions

Outlook

Public comment for code change proposal B11.10.4

From Jordan Jenkins <jenkinsj14@vcu.edu>
Date Tue 3/24/2026 8:34 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:
I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because I work with many individuals with disabilities. They and their care partners deserve a dignified place to change and address bathroom needs. These universal changing tables create a more inclusive public environment, and a better Virginia for everyone.

Sincerely,

Jordan Jenkins, OTS
VCU OTD Class of 2028

Outlook

PUBLIC COMMENT for B11.10.4

From Lauren Ayres <lkaayres@gmail.com>
Date Tue 3/24/2026 9:07 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

Hello,

I would like to make adult-size (universal) changing tables be a requirement in new buildings across the state of Virginia. I believe it will improve many lives dramatically, and wanted to send in my letter of support asking the Board to adopt the changes to the VA state building code!

Regards,
Lauren Ayres

Outlook

Public comment for code change proposal B11.10.4

From Julia Parks <parksj13@vcu.edu>
Date Tue 3/24/2026 9:22 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

Dear Virginia Board of Housing and Community Development,

I am writing in support of proposal B1 1.10.4 which will make adult changing stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because my grandfather is disabled and requires assistance when changing. I am an occupational therapy student, and I value accessibility throughout the lifespan. Inclusivity for individuals with disabilities, older adults, and many other populations is often overlooked, and advocating for their care is essential.

I appreciate you taking the time to read this.

Sincerely,
Julia Parks

Julia Parks, OTS
OTD Class of 2028

Outlook

Public comment for code change proposal B11.10.4

From Julianna Quinn <quinnje@vcu.edu>
Date Tue 3/24/2026 9:52 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development,

I am writing in support of proposal B1 1.10.4. which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me as I am an occupational therapy student, I understand the necessity to grant dignity to disabled adults and their family/caregivers. Please take this monumental step for our disabled adult community members, as they are often forgotten after they are no longer children. These changing tables will not only provide a safe surface for adults to receive care in a dignified manner, but will be beneficial for caregivers as they preserve bodily injury through providing care on a raised surface.
Thank you for your consideration.m

Sincerely,

Julianna Quinn, OTS

Outlook

Public comment for code change proposal B11.10.4

From Marina Chaves <mskchaves@gmail.com>
Date Tue 3/24/2026 9:56 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:
I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because everyone deserves to live with dignity!

Sincerely,
Marina Chaves, OTD/S

Outlook

Public comment for code change proposal B11.10.4

From Rachel Egan <eagsrachel@outlook.com>
Date Wed 3/25/2026 10:06 AM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:
I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because I have a nephew who would greatly benefit from this. His parents struggle with this issue currently and as he grows older it will become a continued hindrance for them all.

Rachel Egan

Get Outlook for iOS

Outlook

Public Comment for B11.10.4

From Catherine Rey <cgrierey@gmail.com>
Date Wed 3/25/2026 1:24 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of Housing and Community Development:

I am writing in support of proposal B11.10.4, which would make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restroom needs while away from home. Currently, countless children and adults that have a disability or medical condition have nowhere to change undergarments or clothing while away from home because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally as the mother of two children with ATR-X Syndrome. My boys are JP (13 years old) and Louie (10 years old), and they have multiple disabilities, including being incontinent, due to their underlying genetic syndrome. Our boys are disabled but they are not disinterested in being active out in the world!

As a family we have been working towards visiting all of Virginia's wonderful state parks since 2020. After visiting the parks closest to us here in Central Virginia, we are now having to take longer road trips to the other regions throughout our state, and along the way, we have had a difficult time supporting our boys' diapering and toileting needs on the road. The best solution we have right now is to find a discreet place in a parking lot, empty out the trunk of our Suburban, and lay the boys down in the back to change them there. We have had to do this in the rain, wind, and freezing cold temperatures, and even when discretion was not readily available, trying to block the boys' bodies with our own to offer them some privacy. As they continue to grow, this system will become less available to us, and we fear that we may become more isolated. We are a family who values Virginia's distinct regions, and we want to continue traveling to these places. Supporting our children's bathroom needs on the road does not have to be this difficult, though: Virginia could choose to invest in family-style bathrooms with adult-sized changing tables.

Please support B11.10.4.

Attached is a photo of our family on a recent trip to James River State Park.



Sincerely,

Catherine, Mike, JP, and Louie Rey

Outlook

PUBLIC COMMENT for B11.10.4

From Sarah Bunger <bunger@vt.edu>
Date Tue 1/20/2026 1:18 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing **in support** of proposal B11.10.4. which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will dramatically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restroom needs while away from home. Currently, countless children and adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or being changed in unsanitary, unsafe, and undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because…

My friend, Evan (pic attached) and my best friend, Erika (Evan's Mom) deserve this kind of world, eventually.

Sincerely,
Sarah Horne

P.s. you gave them a place to park, you gave them entrance in the building, now please, give them a place to use the restroom.

Sarah Brannan Bunger Horne



Outlook

Public comment for code change proposal B11.10.4

From Angela Mesa <trec.angela@gmail.com>
Date Fri 1/16/2026 10:55 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

Good Evening,
To the Virginia Board of housing and community development:
I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adults who have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally as both a Recreation Therapist who serves clients in the community who could greatly benefit from this change and as a mom to a special needs child who has quickly outgrown baby changing tables. This code change could give those with disabilities in our community more freedom and the ability to get out into the community more, as right now they have to schedule time in the community around how frequently they use the bathroom. If they don't, the caregivers often have to resort to changing their loved ones in unsanitary or public places, which can also put caregivers at risk of injury due to transferring their loved ones to the floor.

Please seriously consider what this code change could do for the local disability population and their loved ones/caregivers.

Sincerely,

Angela Mesa



Outlook

PUBLIC COMMENT for B11.10.4

From nora and tom carroll <ntcarroll@yahoo.com>
Date Tue 1/20/2026 4:42 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

As a guardian for a 29-year-old with cerebral palsy, I am writing to express the urgent need for universal adult-size changing tables in public accommodations. While traveling outside the home is essential for community integration, the current lack of appropriate facilities creates significant logistical and safety hurdles.

In many instances, providing necessary care requires two people to assist, and while family restrooms provide privacy, they frequently lack the essential equipment required for dignified care. Standard infant changing tables are physically inadequate and unsafe for individuals weighing over 100 pounds. Without a height-adjustable, adult-size table, a single toileting accident often necessitates an immediate return home. This effectively terminates our community engagement and defeats the goal of inclusive social participation.

The installation of **universal adult-size changing tables** is a critical necessity to ensure that individuals with profound disabilities and their caregivers can access the community with the dignity, safety, and hygiene they deserve.

Outlook

Public comment for code change proposal B11.10.4

From Melissa Rose <melissa@playtimephysicaltherapy.com>
Date Sun 1/18/2026 6:06 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

To the Virginia Board of housing and community development:

I am writing in support of proposal B1 1.10.4. Which will make Adult Changing Stations a requirement in new buildings of certain types in Virginia. By approving this proposal, you will drastically improve the quality of life for many people with disabilities, by giving them access to a safe, private, and dignified place to address their restrooms while away from home. Currently, countless children and adult adults that have a disability or medical condition have nowhere to change undergarments or clothing, while away from home, because they have outgrown baby changing tables. This leads to many of these individuals becoming isolated at home, or changing in unsanitary, undignified places, like the floor of a public bathroom, or on a picnic blanket on the grass, or in their vehicle. Adult Changing stations within family restrooms are essential for us to include all people in community life, regardless of medical condition or disability.

This is important to me personally because…

Sincerely,
Dr. Melissa Rose

Melissa "Missy" Rose, PT, DPT, C/NDT
Owner, Play Time Physical Therapy and Associates
Phone: 757:580-0766
Fax: 757-549-7662

Outlook

Public comment for code change proposal B11.10.4

From Brian Thrower <bthrower0201@yahoo.com>
Date Mon 4/6/2026 7:27 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

I am writing in strong support of Proposal B1 1.10.4, which would require Adult Changing Stations in certain new buildings across Virginia. Approving this proposal is a vital step toward creating public spaces that are truly inclusive and guided by the principles of Universal Design.

Access to a safe, sanitary, and private place for personal care is not a convenience—it is a fundamental matter of human dignity, health, and inclusion. For individuals living with disabilities or complex medical conditions, appropriate changing facilities are essential. Without them, full participation in community life is often limited or impossible.

Adult Changing Stations in family restrooms ensure that individuals of all ages and abilities can access public spaces with dignity. Currently, many people outgrow standard baby changing tables yet have no suitable alternative. As a result, families are often forced into unacceptable situations—such as changing a loved one in a car or on a restroom floor—or may avoid public outings altogether. These barriers are real, and they are preventable.

This issue is deeply personal to me. As a father of a child with multiple disabilities and medical complexities, I understand firsthand the importance of having access to clean, private, and dignified spaces for personal care. The lack of appropriate facilities places an unnecessary burden on families like mine and limits our ability to participate in everyday life.

Requiring Adult Changing Stations in new buildings is a practical and meaningful step toward greater accessibility. It reflects a commitment to inclusion and ensures that all Virginians—regardless of age, ability, or medical need—are able to engage fully in their communities.

This is the kind of Virginia I want to live in: one where every person is respected, supported, and able to live with dignity.

Thank you for your time,
Brian Thrower

Outlook

Public comment for code change proposal B11.10.4

From Monika Thrower <mthrower1@yahoo.com>
Date Mon 4/6/2026 2:02 PM
To codedevelopment (DHCD) <codedevelopment@dhcd.virginia.gov>

I am writing in strong support of Proposal B1 1.10.4, which would make Adult Changing Stations a requirement in new buildings of certain types in Virginia. Approving this proposal is a key step in making our public spaces inclusive, designed to meet the needs of everyone through Universal Design. Access to a safe and sanitary place for personal care is not simply a convenience—it is essential for basic human dignity, health, and inclusion. For individuals living with disabilities or medical conditions, appropriate changing facilities can be life-changing.

Adult Changing Stations in family restrooms are essential to ensuring that all individuals, regardless of disability or medical condition, can fully participate in everyday community life. Implementing this requirement in new buildings is a meaningful step toward accessibility, inclusion, and dignity for all Virginians. Installing Adult Changing Stations within family restrooms is not simply a convenience; it is an essential component of creating inclusive, accessible communities. When we design with Universal Design principles in mind, we ensure that all people—regardless of disability, age, or medical need—can participate fully in community life.

This is important to me personally because as a mom to a child with multiple disabilities and medical complexities, I deeply understand the need for private, clean, and dignified spaces to change undergarments or diapers for loved ones over the age of two. Currently, many individuals with disabilities or medical conditions have no suitable facilities once they outgrow standard baby changing tables. Without such accommodations, families are often forced into unacceptable alternatives—such as changing a loved one in a car or on a restroom floor—or may avoid attending public events altogether. This creates an unintended but very real barrier to participation in community life. Approving this proposal would greatly enhance the quality of life for people with disabilities by providing access to safe, private, and dignified facilities for restroom care while away from home.

When our public spaces include features like Adult Changing Stations, it allows the people I care about to participate fully in community life without barriers, discomfort, or indignity. These improvements reflect the kind of Virginia I want to live in: one where every person is welcomed, supported, and able to engage in daily life with independence and dignity.

Sincerely,
Monika Thrower

B1110.4-24 – Staff Summary

Proponent: Kim Kirkwood and Monika Thrower, representing Changing Spaces Virginia

Brief Description: Expands the list of where adult changing stations are required, to include qualifying mercantile occupancies, state park campgrounds, state park visitor centers, and hospitals.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting — 01/06/2026

Support: Shahriar Amiri, Arlington County; Michael Dellinger, Albemarle County and Virginia Building and Code Officials Association (VBCOA) Region IV; Delegate Elizabeth Bennett-Parker, Virginia House of Delegates 2025, 5th District; Dan Willham, Fairfax County and VBCOA; and Paul Messplay, Hanover County.

Opposition: Mike O'Connor, Virginia Petroleum and Convenience Marketers Association (VPCMA) and Virginia Propane Gas Association (VAPGA).

Discussion:

Monika Thrower provided an overview of the proposal.

a. **Steve Shapiro** asked if there were other organizations that promulgate a standard other than IAPMO Z1390 related to adult changing tables.
b. **Shahriar Amiri** responded that this is an ANSI standard.
c. **Dan Willham** stated that he serves on the Egress Committee for ICC and there was a proposal to add that in.
d. **Dennis Hart** [Virginia Plumbing and Mechanical Inspectors Association (VPMIA), VBCOA PMG Code Committee] added that the standard was approved at the second committee action hearing on a proposal for the 2027 code.
e. **Rick Hinson** [American Council of Engineering Companies (ACEC)] verified for clarification that adult changing stations are already in the 2024 IBC and that this proposal is adding more locations where they would be required.
f. **Mark Graver** (City of Waynesboro, VBCOA Region III) asked the group if everyone was aware of what a "state park visitor center" is as stated in Item 6 and if the term needs to be defined.

g. **Jeff Brown** (DHCD staff) pointed out that the Items 4, 5, and 6 don't have a limitation on the number of fixtures, so these would apply to every state park visitor centers not just based on use group.
h. **Kyle Kratzer** (Fairfax County, Vice President of VBCOA) inquired about directional signage in Section 1110.4.5 and what was the intent.
i. **Monika Thrower** answered that they are looking for an actual sign like what you see for restrooms or elevators.
j. **Shahriar Amiri** offered the example of three banks of toilets and two of them do not have adult changing stations, then you put directional signage to lead you to the toilet that has the adult changing station.
k. **Alyssa Brown** (Changing Tables) stated that when she uses the bathroom, there is signage saying that there are handicapped accessible stalls and there is also signage in family rooms.
l. **David Beahm** (Warren County, VBCOA)suggested that proposed Section 1110.4.6 solves the signage issue.
m. **Mike O'Connor** alerted the group that he is a member of the Statewide Directional Signing Committee that regulates Virginia's blue highway signs. This proposal would require bathroom signage on those signs which are limited to 12 numbers or letters per panel.
n. **Alyssa Brown** warned that anyone could become disabled at any time and how would you feel if you could no longer go into public because of the cost of signage.
o. **Monica Thrower** mentioned that not every disability is the same. Monica T and her son can be totally secluded if she does not have somewhere to go to change her son who is totally dependent on her.
p. **Delegate Elizabeth Bennett-Parker** claimed that this issue is important for inclusivity, accessibility and dignity, and courage.
q. **Mike O'Connor** expressed this proposal has not been heard by the workgroups and that there has been no outreach to outside industries.
r. **Shahriar Amiri** responded to Mike O's comment that these discussions take place at the ICC level and the A117.1 committee has been working on this for a long time.
s. **Paul Messplay** mentioned that this proposal has nothing to do with Mike O's comment regarding VDOT signage.

DHCD Staff Note: N/A

B1210.1.1-24

IBC: 1210.1.1 (New)

Proponents: Tanya Pettus, representing Self/Public Interest

2024 International Building Code

Add new text as follows:

1210.1.1 Required public restroom fixtures.

All public restrooms, whether a separate room or water closet compartment, must be equipped with a mounted hook or hook-like fixture capable of securely holding up to ten pounds, and reasonably accessible from the toilet.

Reason Statement: Mounted hooks should be required in all public restroom facilities, whether single toilet rooms or water closet compartments, to accommodate those who need to carry medical equipment but are otherwise mobile or ambulatory. Necessary medical equipment should not be placed in a public restroom floor in the absence of a hook or fixture that can hold the equipment, and this is not a problem handicap accessible stalls can solve, as hooks are not always present and grab bars are not designed or installed in such a way as to be used for makeshift shelving.

As an example, a portable oxygen machines that can be carried over the shoulder typically weigh about ten pounds. Without a hook, a person connected to this type of machine will have to steady or hold this additional ten pounds while navigating the restroom or be forced to place the machine on a public restroom floor. An oxygen machine is connected to its user by a cannula that could potentially bring bacteria from a public restroom floor directly into an already ailing person's nose.

Consider requiring hooks in all public restrooms, not only for the millions of people who use supplemental oxygen or other required medical equipment, but for general public safety and wellbeing to prevent contamination of personal items. Trends in Lung Disease | American Lung Association: https://www.lung.org/research/trends-in-lung-disease

Cost Impact: The code change proposal will not increase or decrease the cost

Costs of coat/utility hooks are minimal, with the consumer retail price beginning at less than $1.00.

Amazon.com: 25 Pack Coat Hooks Wall Hooks for Hanging, Heavy Duty Double Prong Metal Hook Wall Mounted for Living Room, Bathroom, Kitchen, Bedroom for Coat, Bag, Scarf, Towel, Hat, Key, Cup (Black) : Home & Kitchen
Zinc, 2 1/4 in x 1 3/8 in x 3 in, Coat Hook and Bumper - 1ECL2|1ECL2 - Grainger

Coat - Hardware - Wall Mounted - Individual Hooks - Hooks - The Home Depot

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25 Pack Coat Hooks Wall Hooks for Hanging, Heavy Duty Double Prong Metal Hook Wall Mounted for Living Room, Bathroom, Kitchen, Bedroom for Coat, Bag, Scarf, Towel, Hat, Key, Cup (Silver)

4.7 (2,215)

- 【MULTI-SCENARIO】hooks for hanging Coat can be used in the living room, kitchen, bedroom, bathroom, hanging a variety of daily necessities
- 【QUALITY MATERIALS】The hanging heavy duty wall hooks are made of zinc alloy, sturdy and durable with a maximum load capacity of 40 lbs
- 【SUPERB CRAFTSMANSHIP】The hooks for hanging are finely polished with smooth edges, high quality plating with matte coating, wear-resistant and rust-resistant
- 【SPACE SAVING】This coat hook can create an orderly and tidy space keep your space well organised
- 【EASY TO INSTALL】The closet hooks are easy to install, you can easily install the screws to the wooden surface
- 【PACKAGE AND SIZE】: the package includes 25pcs Silver coat hooks and 50pcs screws with the right length, the size is 2.8 x 1.77 inches and the screws are 0.75 inches

› See more product details

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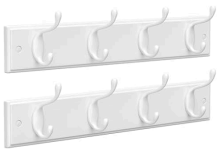
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Tebgeag 8 Pack Wall Hooks for Hanging, Heavy Duty Coat Hook Wall Mount, Easy to Ins...
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Antimbee 10-Pack All-Purpose Large Adhesive Hooks for Hanging, Banana Hook, Heavy D...
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ZESLMG Adhes Hooks for Hang Pack Self Sticky Heavy Duty 22l
3,

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IBosins 6 Pack Big Heavy Duty Three Prongs Coat Hooks Wall Mounted with 24…
2,084
$9.99 ($1.67 / count)



IBosins 15PCS Coat Hooks Wall Mounted Single Prong Robe Hook for Hanging Towel…
3,235
$9.99 ($0.67 / count)



Heavy 316 Duty Stainless Steel J-Type Wall Hooks, Marine Grade Wall Hanger…
3
$10.99 ($5.50 / count)



IBosins 12 Pack Antique Brass Coat Hooks Wall Mounted with 24 Screws Retro Double H...
5,479



IBosins 2 Pack Rack Wall Mou Wood Color Co Hanger, Rustic
3

From the brand

About Us

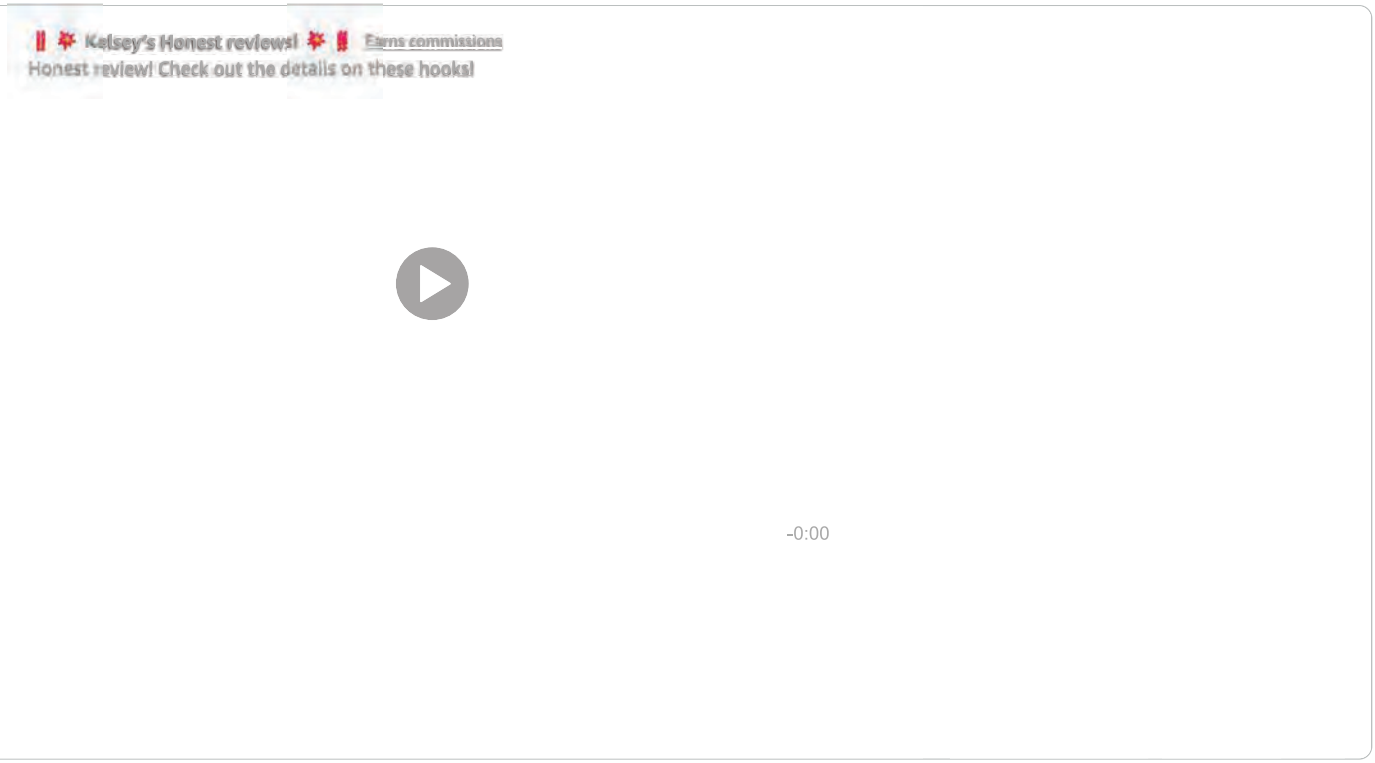
A home designer launched CBWLWJ to create stylish, sturdy hooks. Guided by "Crafting Life with Dedication", we merge art and utility.

Inspired by art, our hooks come in modern and vintage styles. Made from top materials, they pass strict load - bearing, wear, and rust tests.

CBWLWJ hooks are now loved worldwide for blending storage with style. We'll keep innovating for better living.

Product description

Product Videos



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Black Coats Towels Hooks,Towel Robe Clothes Coat Hooks,Heavy Duty…
579



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5,479



IBosins 2 Pack Coat Rack Wall Mount, 17" Old Wood Color Coat Hanger, Rustic Wooden...
381



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342



IBosins 10 Pack Dual Coat Hooks Wall Mounted with 40 Screws Retro Double Hooks…
2,356



IBosins 6 Pack Heavy Duty Thr Prongs Coat Hc Mounted with 2
2,

Brands in this category on Amazon

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Customer reviews

4.7 out of 5

Customers say

2,215 global ratings

5 star 84%
4 star 10%
3 star 4%
2 star 1%
1 star 1%

How customer reviews and ratings work

Customers find these wall hooks to be of good quality, easy to install with included screws, and appreciate their glossy finish and storage capacity for various items. They work particularly well for kids' coats, backpacks, and hats, and offer good value for money. Durability receives mixed feedback - while some find them sturdy enough to hold full backpacks, others report that the hooks break easily. The screw quality is also mixed, with some customers reporting issues with the provided screws.

Generated from the text of customer reviews

Select to learn more

✓ Quality (101) | ✓ Ease of installation (62) | ✓ Value for money (51) | ✓ Look (47) | ✓ Works well (40) | ✓ Storage capacity (30) | — Durability (97) | — Screw quality (34)

Reviews with images

See all photos ›






Top reviews from the United States

LL

Economical way to get these

Reviewed in the United States on October 12, 2025

Verified Purchase

These hooks, sold individually, are ridiculous prices at the big box stores - if you need them, THIS is the place to get them.

I was making this entryway key organizer and had a smaller area below the mail shelf to get hooks on - this size was exactly right. Now I have the organizer done, and hooks to spare. The hardware is good, no issues on installation, the hooks are a good weight and finish...sturdy and solid, these hooks will hold.




2 people found this helpful

Helpful Report

Kim

Inexpensive and awesome!

Reviewed in the United States on October 15, 2025

Verified Purchase

I put these on the back of every bedroom door and bathroom door in my house for the kids to hang up their wet towels. Do they use them? No! But they're still awesome. Note: my doors are solid wood. If you have hollow doors, the door and the screws won't support weight.

I also made a coat rack in the garage for jacket snow pants and backpacks. Are they using it? Not yet, but they better start, because they're not coming in the front door this winter and dragging all that yuck in my house.

These are awesome, kids need training. So far I haven't had one screw or one hook break. I hang dry heavy things on them. Still holding up. Another note, don't hang this directly on drywall, at least not with these screws. Drywall is not strong enough.




4 people found this helpful

Helpful Report

Marvin

Sturdy

Reviewed in the United States on February 11, 2026

Verified Purchase

First I'll say esthetically they look sleek and sorta high end, love the matte black. I installed two on a sheet rock wall, first having installed wall anchors that I also got on Amazon. They're holding up well and they're pretty solid they don't feel cheap. I have 2 backpacks hanging on one and a couple of winter coats hanging on another. Time will determine the wear and tear and I'll write an update eventually, but so far so good.

Helpful Report

Miranda L.

Worked well for us

Reviewed in the United States on February 5, 2026

Verified Purchase

Loved these for our coat wall. Easy to install (we didn't use the anchors) and hold coats/backpacks (with chromebooks) for our 5 kids no problem.



Helpful Report

Fred Vaughn

Work Uniforms accessories

Reviewed in the United States on September 19, 2025

Verified Purchase

Good product, good price

One person found this helpful

Helpful Report

Brianna Finley

So happy

Reviewed in the United States on December 6, 2025

Verified Purchase

The hooks that came with this wrack SUCKED and broke. They were so flimsy and could hardly hold 2 coats. We just put these hooks up and I am SO happy with them. We are able to hang up so much more than before and it is very clear that these hooks are heavy duty and will absolutely suit our needs. They are a good thickness, they screwed in easily and hold firmly to our wrack.



One person found this helpful

Helpful Report

The Pine & Palm Edit

Good quality and great for towels!

Reviewed in the United States on February 11, 2026

Verified Purchase

Great quality and easy to use. They were perfect for our new bathroom towel wall and seem like they will last a long time. We even had a couple extras.



Helpful Report

Cassandra Craig

Nice and sturdy

Reviewed in the United States on January 27, 2026

Verified Purchase

These are pretty nice. Sturdy. Easy to hang



Helpful Report

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English United States

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Hook Type: Coat **Mount Location:** Wall Mounted **Hook Configuration:** Individual Hooks **Included:** Hardware Clear All

Exclusive



Liberty Rustic Farmhouse 3.07 in. Flat Black Single Prong Hook
(4.8 / 308)
Model# B43199-FB-CP

$4.27

Pickup: 23 in stock at Ashburn
Delivery: Free | Tomorrow
Faster Delivery: Get it Today

Add to Cart



Liberty Ruavista 4.38 in. Flat Black Coat and Hat Hook
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Model# B21845Z-FB-CP

+more

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Exclusive

Magic Apron Assistant



Liberty Pilltop 5.63 in. Flat Black Hook

(4.8 / 129)

Model# B45006Z-FB-C

$6.27

Top Rated



Liberty Rustic Farmhouse 3 in. Flat Black Double Prong Hook

(4.5 / 144)

Model# B43198-FB-CP

$5.27

Exclusive



Liberty 5-5/8 in. Satin Nickel Pilltop Coat Hook

(4.8 / 311)

Model# B45006Z-SN-C

to Cart

+more

$6.27



Liberty Hardware 4.25 in. H 35 lbs. Weight Capacity Matte Black Lea…

(4.8 / 150)

Model# B43193-FB-CP

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$7.57

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Top Rated



Liberty 4-3/8 in. Satin Nickel Beveled Square Wall Hook

(4.8 / 276)

Model# B31094C-SN-C

$7.97

Exclusive



Liberty 2.88 in. Satin Nickel Elephant Hook

(4.8 / 224)

Model# B43194-SN-CP

$10.47

Pickup: 14 in stock at Ashburn

Delivery: Free | Nov 6 - Nov 7

Faster Delivery: Get it Today

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Pickup: 13 in stock at Ashburn

Delivery: Free | Today

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Feedback

Exclusive



Liberty Simple Square 2.88 in. Flat Black Single Prong Hook

★★★★★ (4.8 / 122)

Model# B43206-FB-CP

$5.57

Pickup: 8 in stock at Ashburn

Delivery: Free | Nov 6 - Nov 7

Faster Delivery: Get it Today

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Amerock Emerge 5-7/16 in. L Satin Nickel Double Prong Wall Hook

★★★★★ (5 / 5)

Model# H37003G10

+more

$9.94

Ship to Store: Free | Pickup

Delivery: Free | Nov 6 - Nov 7

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Amerock Alder 4-1/2 in. L Matte Black Double Prong Wall Hook

★★★★★ (5 / 15)

Model# H37007MB

$19.42

Ship to Store: Free | Pickup

Delivery: Free | Nov 6 - Nov 7

Add to Cart

Exclusive



Liberty Modern Round 2.75 in. Champagne Bronze Post Hook

★★★★★ (4.9 / 48)

Model# B43153-CZ-CP

$7.93

Pickup Nearby: 11 in stock at South Riding (5.9 mi)

Delivery: Free | Nov 6 - Nov 7

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idh by St. Simons Polished Brass Solid Brass Coat and Hat Hook

★★★★☆ (3.8 / 6)

Model# 17020-003

+more

$2.65



Amerock Vicinity 4-9/16 in. L Champagne Bronze Triple Prong…

★★★★★ (4.9 / 7)

Model# H37004CZ

+more

$12.66

Ship to Store: Free | Pickup
Delivery: Free | Mon, Nov 10

Add to Cart

Ship to Store: Free | Pickup
Delivery: Free | Nov 6 - Nov 7

Add to Cart



Richelieu Hardware 2-1/8 in. (54 mm) Brushed Nickel Transitional…
(5 / 1)
Model# BP7952195

$21.53

Ship to Store: Free | Pickup
Delivery: Free | Nov 5 - Nov 6

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Amerock Medium 3-5/16 in. Satin Nickel Coat and Hat Hook
(4.6 / 16)
Model# H55445G10

$5.93

Ship to Store: Free | Pickup
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Add to Cart



Liberty 3-1/2 in. Matte Black Heavy Duty Coat Hook
(4.7 / 461)
Model# B42302Q-FB-C5

+more

$4.99

Ship to Store: Free | Pickup
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Amerock Adare 5-1/2 in. L Champagne Bronze Double Pron…
(5 / 7)
Model# H55465CZ

$5.98

Ship to Store: Free | Pickup
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Exclusive



Richelieu Hardware 1 in. (25 mm) Stainless Steel Contemporary Wa…

(1 / 1)

Model# 51124170

$22.28

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Delivery: Free | Nov 5 - Nov 6



Home Decorators Collection 4-Pack 3 in. Alloy Matte Black Folding 35…

(3.1 / 12)

Model# 64361

$15.88

Ship to Store: Free | Pickup

Delivery: Free | Wed, Nov 5



DANYA B Black Cast Iron Railway Spike Wall Mount Hook Set (Set …

(4.9 / 7)

Model# SW305

$34.99

Ship to Store: Free | Pickup

Delivery: Free | Fri, Nov 7



Amerock 25 lb. Oil-Rubbed Bronze Large Double Coat and Hat Hook

(4.8 / 32)

Model# H55451ORB

$4.56

Ship to Store: Free | Pickup

Delivery: Free | Nov 6 - Nov 7

Add to Cart

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Liberty 5-1/5 in. Matte Black Ball End Coat Hook
(4.8 / 53)
Model# B46305C-FB-C

$5.81

Ship to Store: Free | Pickup
Delivery: Free | Nov 6 - Nov 7

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Amerock Alder 4-1/2 in. L Champagne Bronze Double Pron…
(4.9 / 17)
Model# H37007CZ

$19.42

Ship to Store: Free | Pickup
Delivery: Free | Nov 6 - Nov 7

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(4.8 / 308)
$4.27
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Liberty Pilltop 5.63 in. Flat Black Hook
(4.8 / 129)
$6.27
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Exclusive



Liberty Hardware 4.25 in. H 35 lbs. Weight Capacity…
(4.8 / 150)
$7.57
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Richelieu Hardware 5-3/4 in. (146 mm) Stainless…
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(4.2 / 833)

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(4.7 / 184)

$4.93



Command Command Large Utility Hooks, White, Damage…

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Provide Feedback





APPROVED VENDOR Coat Hook and Bumper: Zinc, 2 1/4 in x 1 3/8 in x 3 in, 2 in Max. Panel Thick

Item **1ECL2** Mfr. Model **1ECL2**

Web Price
$7.10 / each

Qty 1 **Add to Cart**

Ship | Pickup

Expected to arrive **Fri. Mar 06**.

Ship to **20146** | Change

Shipping Weight **0.15 lbs**

Ship Availability Terms

Add to List

Product Details

Catalog Page **2644**

Brand **APPROVED VENDOR**

Manufacturer Part Number **1ECL2**

Hardware Pieces Included **(2) Screws #8 x 3/4 in**

Includes **Mounting Screws**

Hardware Material **Zinc**

Maximum Panel Thickness **2 in**

Overall Dimensions- H x W x D **2-1/4 in x 1-3/8 in x 3 in**

Overall Height **2-1/4 in**

Overall Width **1-3/8 in**

Overall Depth **3 in**

UNSPSC **31162606**

Country of Origin **Taiwan (subject to change)**

Product Description

These hooks attach to bathroom partition walls and doors to provide a spot to hang clothes, towels, or other personal items.

Compliance & Restrictions

WARNING: Cancer and Reproductive Harm - www.P65Warnings.ca.gov

Agent Chat

B1210.1.1-24 – Staff Summary

Proponent: Tanya Pettus, representing Self/Public Interest

Brief Description: Requires installation of a hook, suitable for supporting medical equipment up to 10 lbs., near every toilet in public restrooms.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting — 01/06/2026

Support: None

Opposition: Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA); and Dan Willham, Fairfax County and Virginia Building and Code Officials Association (VBCOA).

Discussion:

Jeff Brown (DHCD staff) provided an overview of the proposal.

i. **Steve Shapiro** recommended that this proposal should be introduced at the national level first and questioned where the ten-pound requirement comes from.

DHCD Staff Note: N/A

B2403.6-24

VCC: 2403.6 (New), 2403.6.1 (New), Chapter 35 (New)

Proponents: William Penniman, representing Northern Virginia Bird Alliance (wpenniman@aol.com); Thomas Blackburn, Northern Virginia, representing Northern Virginia Bird Alliance (tomlblackburn@gmail.com); Sonal Shah, Northern Virginia, representing Northern Virginia Bird Alliance (moiforte@gmail.com)

2021 Virginia Construction Code

Add new text as follows:

2403.6 Bird-Friendly Design and Construction. Within the Bird Activity Zone of any new building construction and other High-Risk Building Features and High-Risk Auxiliary Structures, not less than 85% of all exterior envelope material including Glass and Reflective and/or Transparent Non-Glass Materials as calculated at each of the facades of buildings shall be of Bird Friendly Material as defined in 2403.6.1.

2403.6.1 Definitions.
Bird Activity Zone. The zone from zero to 75 feet above grade (using the average between lowest to highest grade along slopes).
Bird-Friendly Material. Bird-Friendly Glass and exterior envelope materials that are non-transparent (such as traditional outside walls of wood, brick, concrete) and not highly reflective or have a Threat Factor Rating of 30 or less as determined and published by the American Bird Conservancy. See www.birdsmartglass.org for Threat Factor database.
Bird-Friendly Glass. Glass, other glazing materials or screening that meet any of the following conditions:

- Frosted or opaque glass or glass with exterior surface (surface 1) obstructed and effectively covered by building-integrated structures that do not have gaps larger than 12" in any dimension, including non-glass double-skin facades, metal screens, fixed solar shading, exterior insect or unglazed solar screens, grilles, child guards and other features that meet these conditions.
- Un-tinted glass with an outer total reflectance of ≤15% that contains a pattern of visual markers that conforms to the following rules: (i) dots or other isolated solid shapes that are ≥¼" in diameter and are either ≤ two-inches (2") apart in horizontal lines and ≤ two inches (2") apart in vertical lines or ≤ (ii) two-inches (2") apart if randomly distributed or (iii) horizontal lines that are ≥⅛" in width and spaced ≤2" apart or (iv) vertical lines that are ≥⅛" in width and spaced ≤2" apart.
- Any glass or glazing product with a Threat Factor Rating of 30 or less as determined and published by the American Bird Conservancy. See www.birdsmartglass.org for Threat Factor database; or that follows American Bird Conservancy's Prescriptive Rating Criteria. abcthreatfactor.org.

High-Risk Building Features. Transparent or highly reflective external surfaces of any of the following building features: skyways/skywalks; building connectors; outside corners where a bird can see in one side of the building and out the other ("fly through conditions"), within 30 feet of the corner; parallel glass walls less than 50 feet apart; courtyards, including atria, open to bird entry; 20 feet of glazing adjacent to and above green roofs.

High-Risk Auxiliary Structures. Structures with glazing that pose significant collision risks to birds wherever they are found, including but not limited to:

- Transparent or highly reflective railings or barriers, including along balconies; noise or wind barriers (including parking structures) or weather shelters.
- Small, stand-alone buildings that present conditions that can be either transparent or reflective such as gazebos and external ticket booths.
- Any other free-standing glass, plexiglass, or other clear, transparent, or highly-reflective free-standing structure.

Glass. All glass, including spandrel glass.
Reflective and/or Transparent Non-Glass Materials. Any non-glass materials that are transparent or highly reflective, including but not

limited to plexiglass and polished metal.

Revise as follows:

Chapter 35 Referenced Standards. Add new standard promulgator and new standard, as follows:

ABC American Bird Conservancy

P.O. Box 249, The Plains, VA 20198

Threat Factor Rating System for bird-safe windows (https://abcbirds.org/wp-content/uploads/2025/06/What-is-a-Threat-Factor-6-9-25.pdf)

Reason Statement:

This proposal is supported by the Northern Virginia Bird Alliance.

Collisions with buildings kill up to1 billion birds per year in the United States primarily due to the "invisibility" of clear glass to birds and due to reflections that appear to be attractive places to fly into. https://abcbirds.org/glass-collisions/why-birds-hit-glass/ This high annual loss of birds to building collisions has contributed to the significant decline that has been recorded in many bird populations during recent decades.

The danger to birds exists for the full height of buildings, since migratory birds can hit a building at any level. While taller buildings pose a greater danger on a per-building basis,

most collisions involve glass on homes and buildings up to 10 stories because of the prevalence of such buildings. https://abcbirds.org/glass-collisions/why-birds-hit-glass/ The amount of glass is the strongest predictor of bird collisions. The choice of design and glass can reduce collisions by a significant amount. https://abcbirds.org/glass-collisions/architecture-planning/

Clear glass is a threat whether it is part of the building envelope or an extension of glass above the building walls or incorporated into skyways or balconie

Although the risks extend to the tops of the tallest buildings, the American Bird Conservancy proposes defining the "bird activity zone" as being up to 100 feet above grade where both local flights and migrations occur. This proposal is generally modeled upon ABC's proposal with some effort to simplify the language and moderate the requirements including reducing the height requirement to 75 feet above grade. It is important to note that portions of structures without glazing, other transparent or high-reflective cladding are not affected. Above-grade parking structures without glass, for example, are not affected.

Bird-friendly solutions may involve building design, the glass itself (e.g., frits or printed patterns, coatings, frosting) or physical structures (as simple as window screens, grills, shades or less glazing). See https://abcbirds.org/glass-collisions/architecture-planning/ ("Bird Friendly Design Guide"); https://abcbirds.org/glass-collisions/why-birds-hit-glass/ ; https://abcbirds.org/glass-collisions/photo-gallery/ ; https://www.collidescape.org/

As illustrated by the Javits Center window replacement, the choice of bird-friendly glass can reduce collisions by over 90%. https://abcbirds.org/glass-collisions/architecture-planning/

The range of bird-friendly glazing and designs is growing as architects, builders and glass companies make concerted efforts to minimize building threats to birds. See, for example:

https://abcbirds.org/glass-collisions/products-database/

https://nationalaudubon.app.box.com/s/lmf7vijbohuds6j92igzl1dzy8398ckj

https://www.featherfriendly.com/commercial?hsLang=en ;

https://www.birdsavers.com/

A simple, collision-deterrence rule for spacing of markings on glass is the so-called "2X2" standard: two-inch spacing horizontally and vertically based upon the physical profile of a bird in flight. Current research has established the appropriate maximum module dimensions of 2"high X2"wide. Some solutions, such as films meeting the 2"X2" standard, can be applied to windows as an alternative to fritting/etching.

Depending on designs and materials chosen, the solutions may be essentially invisible to occupants (e.g. UV patterns) or fit with the overall design pattern (e.g. insect screens on windows) or be such (e.g. frits) that occupants quickly get used to and see beyond the faint patterns.

The American Bird Conservancy maintains and continuously updates a list of tested bird-friendly materials, which can be used for compliance in order to provide flexibility for builders and architects. The ABC lists bird-friendly materials and rates products based on the hazard they pose for birds ("ThreatFactor"). https://abcbirds.org/glass-collisions/threat-factor-rating/ The data base is available in printed form or found at https://abcbirds.org/glass-collisions/products-database/; www.birdsmartglass.org. As of August 2025, there were nearly190 bird-friendly glazing products that had been tested and found to pass the ABC's "threat" standard.

Government bodies around the country have begun to address the issue of fatal bird collisions with mandatory standards for bird-friendly construction. The ABC Threat Factor Rating is based upon testing and is commonly cited (e.g. by NYC, D.C. and GSA) as

a source of acceptable compliance standards.

This proposal will enhance the resiliency and survival of both local and migratory birds, which are currently killed and injured by impacts to windows and ot rise buildings. Bird populations have declined substantially in the United States in the past 50 years, in significant part due to buildings and increased quantities of glass used in construction.

By implementing the requirements for Bird-Friendly Materials in new construction, adoption of the proposal will substantially reduce bird injuries and mortality. As illustrated by the 90% reduction of bird mortality by installing bird-friendly glazing on the Javits building, experience indicates that the reduction of bird injury and mortality could be huge with full implementation.

Cost Impact: The code change proposal will increase the cost

The proposed provision may, but need not, increase building costs. See https://abcbirds.org/glass-collisions/architecture-planning/ ("Bird Friendly Design Guide": "New construction can incorporate from the beginning bird-friendly design strategies that are cost neutral.").

Some approaches can raise costs of construction, since bird-friendly glass is somewhat more costly than traditional glass. However, patterns on glass are only one solution. Design decisions for new buildings can mitigate or eliminate increased costs. For example, design changes to reduce the glass areas can result in reduced construction costs and also save operational costs with a more efficient building envelope and lower energy consumption. Many non-glass solutions, such as screens, sunshades or less glass, are cheaper and have other benefits.

Additional costs related to bird-friendly glass are incurred only at the product level, there are no additional installation or labor costs involved. Recent cost data received from regional general contractors for two (2) mid-rise (10 - 12 stories) commercial construction projects is listed below:

Project 1:

Total project size and cost: 544,000 GSF, $140 million

Total glazing costs: $7.75 million

Total additional costs for Bird-Friendly frit design: $610,000 or 0.43% on overall project costs and 7.87% on overall glazing costs.

Project 2:

Total project size and cost: 380,000 GSF, $128 million

Total glazing costs: $15.7 million

Total additional costs for Bird-Friendly frit design: $1.14 million or a premium of 0.89% on overall project costs and 7.26% on overall glazing costs.

In another example, construction of a building with 9,500SF of glass incurred higher building costs of "less than a fifth of a percent of total construction costs".https://livingbuilding.kendedafund.org/2019/04/26/kended buildings-bird-safe-glass-shockingly-huge-issue/.

The manufacturing market for bird-friendly glass andother bird-friendly solutions has become more competitive and therefore cost effective. All major manufacturers have a range of Bird-Friendly glass options available and several products are in late research and development stage with market readiness only a few months away.

We believe this allows designers and owners to choose from a range of options that help realize aesthetic, budget or performance goals or all of the above.

Frequently Asked Questions About Birds and Glass

Glass collisions kill vast numbers of birds in the United States each year. Yet most Americans know little about this danger, and even fewer are aware of the solutions available to help prevent these deaths — fixes that in many cases are easy and inexpensive.



To shed light on this pervasive threat, ABC's collisions experts, Christine Sheppard, Ph.D., and Bryan Lenz, Ph.D., put together a list of responses to the 15 questions they are most frequently asked. Take a look. Chances are, we've got an answer for you below.



Birds killed by glass collisions in Toronto. Photo by FLAP/Kenneth Hrdy

1) How many birds are killed by glass collisions in the U.S. each year?

Because glass is used so widely, giving a definitive answer is difficult, but Smithsonian researchers attempted to do so in 2014.

They estimated that homes and other buildings one to three stories tall accounted for 44 percent of all bird fatalities, about 253 million bird deaths annually. Larger, low-rise buildings four to 11 stories high caused 339 million deaths. And high-rise buildings, 11 floors and higher, kill 508,000 total birds annually. Individual skyscrapers can be quite deadly for birds, but they kill fewer birds overall due to their limited numbers.

By combining these numbers, the Smithsonian reported that collisions likely kill between 365 million and 1 billion birds annually in the United States, with a median estimate of 599 million1.

We believe that the true number is closer to a billion, or higher, for several reasons. For one, data used in the study is now more than ten years old, and there has been a steady increase in glass use since that time, increasing the likelihood of fatal collisions. In addition, we've learned that bird carcass reports tend to underestimate deaths (see questions 4 and 5), meaning that more dead birds go uncounted than we realized.

This means that the only anthropogenic (human-caused) threat that kills more birds in the United States each year is domestic cats2.

2) Why do birds collide with glass?

Transparent glass is invisible to both humans and birds, but humans can use door frames and other visual clues to anticipate the presence of glass and avoid collisions — most of the time. Birds, of course, don't share this ability. They perceive reflected images as literal objects, which explains why glass reflections, especially ones that present images of food, shelter, or an escape route, can trigger collisions. Learn more by visiting our "Why Birds Hit Glass" page.



Reflections can draw birds toward windows. Photo by Christine Sheppard

3) Are birds okay when they hit windows and fly away?

After colliding with glass, some birds may be only temporarily stunned and without lasting injury — but often they are not so lucky.

In many of these cases, birds suffer internal hemorrhages, concussions, or damage to their bills, wings, eyes, or skulls3. While they may be able to fly temporarily, birds with even moderate injuries are much more vulnerable to predators and other environmental dangers.

In many instances, however, birds are killed immediately and never fly away.

4) Why don't I see birds that have been killed by collisions more often?

Collisions often go unnoticed at both homes and commercial buildings for several reasons. First, many of the birds that hit windows do not die immediately and fly off without leaving a trace.

One study found that, out of 29 window collisions, only two birds died immediately and left a carcass that at the foot of the window4. However, birds can sustain severe injuries such as fractured bones and beaks, concussions, and internal bleeding3, so even birds that initially fly away likely die elsewhere.

Second, for those birds that do die and end up at the base of the building, animal scavengers often quickly remove carcasses. Cats, raccoons, birds of prey, and even squirrels, can learn to wait at windows where collisions occur for an easy meal.

Birds may also fall on inaccessible rooftops, fall through grates, end up in landscaping, or land in dense vegetation that makes them difficult to see.

5) Do collision monitoring programs find all collision victims?

Even for intensive collision monitoring programs the total number o always a large underestimate of the number of birds that actually collided with the glass. This is the cas the answer above.

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American Bird Conservancy Donate

Many of the birds that hit windows do not die immediately and fly off without leaving a trace. One study found that, out of 29 window collisions, only two birds died immediately and left a carcass that at the foot of the window4. However, birds ca vere injuries3, so even birds that initially fly away might die elsewhere.

Second, for those birds that do die and end up on the ground, animal scavengers – and people, frequently facilities teams – often remove carcasses before monitors can find them. Collision monitors even report animals, such as gulls and squirrels, learning to wait at windows where collisions occur for an easy meal. This problem is so serious that academic monitoring efforts conduct “carcass persistence studies” to estimate the number of dead birds removed before monitors walk their routes and find them5,6.

The rate at which dead and injured birds disappear can vary a lot from site to site7; researchers have found that in some places carcasses are removed within hours8 while at others it takes days5,6,7. At some locations in NYC, for example, only 25% of carcasses placed on collision monitoring routes remained when collisions monitors walked their routes later the same morning8.

Finally, for those birds that are left, monitors do not always detect all of them9. Birds may fall on inaccessible rooftops, fall through grates, end up in landscaping, land in dense vegetation that makes them difficult to see, be swept away in the gutter, or just overlooked because they blend in with the ground.

In one study where researchers accounted for both scavenging and imperfect detection, they estimated that only about 20% of birds killed were actually found by people who were searching for them9. So, it is safe to say that any number of birds picked up in a monitoring effort especially if it is not a rigorous monitoring effort, is going to be a small fraction of the birds that actually died and an even smaller fraction of the total number of birds that hit the windows.

6) How do I stop birds from hitting my windows?

There are many ways to making windows bird-friendly. One of the best is to use external insect screens. These screens virtually eliminate reflections, and if birds do hit them, the impact is cushioned, reducing the likelihood of injury. An added benefit is that these screens are easy to install on existing or new home windows.

If screens aren’t an option, you can use a range of materials — tape, decals, strings, cords, paint, netting, and shutters are options — to create window patterns that birds will interpret as solid objects, needing to be avoided. Check out our great home-friendly solutions guide here.

It’s important to make sure that birds see no viable way to fly between the markers or objects you’re using, so make sure to eliminate all spaces larger than two inches.

Remember, whichever material you use needs to be visible to birds from at least ten feet away so that they have time to see the material and change course.



Bird-friendly window products are effective, inexpensive, and easy to install. Photo by ABC

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7) Can I apply something to the inside of my windows to stop bird collisions?

The best place to apply solutions is on the outside of the window, where they are easily visible.

However, using external solutions isn't always an option. Some windows — like those on tall buildings — can be difficult to access from the outside.

In these cases, we recommend testing a variety of solutions. This is because different kinds of glass have varying reflective levels and, unfortunately, there is no universal solution.

To conduct a test, apply a sticky note, tape, or sample of your proposed solution to the inside of the window and then look at it from the outside every hour or two, starting in the early morning.

If you can see your test material most of the time, birds will too, and an inside solution may work for you.

In many cases, however, internal solutions do not work, and reflections will hide your solution during part or all of the day, thereby reducing or eliminating its effectiveness.

But this shouldn't deter you from acting. is better than doing nothing. Adding something to your windows is better than doing nothing.



The intensity of window reflections varies during the course of the day, affecting the danger to birds. Photo by Christine Sheppard

8) Will bird-friendly window products obscure the view from my window?

No, you don't need to impair your view to save birds.

There are effective solutions that cover as little as 1% of the window area, allowing sunlight in and a view out. In our experience, people quickly adjust to bird-friendly design solutions, often forgetting that they are even there. We have also found that when family, friends, or customers notice the pattern and learn its purpose, they appreciate the effort to protect birds.

If you're looking to retrofit existing windows, there is a wide range of solutions from which to select, depending upon personal preferences.

If you are designing a new building or replacing windows, consider the professional solutions favored by architects. Many of these elegant products have enjoyed long-standing popularity among architects for their aesthetic appeal alone. For more on designing a new building or replacing windows, visit the "Resources for ArchiteSkip to main contentelopers" page. Looking for inspiration? Check out our bird-friendly building gallery.



Bird-friendly window products have little impact on views. Photo by Arenal Observatory Lodge

9) Does light cause birds to hit buildings?

Light can increase collision numbers in several ways. Recent studies confirm that urban glow attracts birds into the human-built environment[10,11], where they run a higher risk of collisions.

Migratory birds traveling at night are also attracted by intense lights contrasted against the night sky. The “beacon effect,” as this occurrence is commonly known, can be caused by lighthouses, offshore oil platforms, or powerful light displays, like the twin beams at the 9/11 Tribute in Lights memorial in New York City. These lights can thoroughly disrupt birds’ ability to navigate, pulling them off course and effectively trapping them around the light12 or disorienting them. At the 9/11 memorial, volunteers monitor the birds and the lights are turned off when needed to allow safe passage.

Brightly lit building facades can also affect birds. In some cases, these facades and brightly lit windows can cause collisions at night[13,14]. These birds are seen fluttering at lit windows or exhausted on the ground14 where they are vulnerable to predators.

Despite the dangers posed by nighttime lights, it’s important to note that most collisions take place during the day. These collisions are due to habitat reflected in or seen through glass, and they are often direct and deadly.

While turning off lights is a great way to help birds and other wildlife, the best way to prevent collisions, especially at homes, is to use one of the many options available to treat your windows.





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The World Trade Center memorial light has a “beacon effect” upon birds. Photo by jnap/Flick. Houston, [illegible] nonstrates the growing impact of light pollution. Photo by NASA

10) I put a decal up, but birds still hit my windows. What can I do?

A single decal may be enough to warn an alert human to expect a glass door, but for a bird it's simply an obstacle to fly around.

To successfully deter birds, decals and other collision deterrents must be applied with proper spacing to create the illusion of a cluttered environment through which it would be difficult or impossible to fly. You can learn more here. Remember to make sure that whichever pattern you use on your windows should not have any spaces more than two inches wide.

11) What can I do about a building that causes collisions in my town?

The first thing to do is document the problem. Take photos of the dead birds you find and keep a list of numbers and dates.

If there is a facilities or maintenance department, ask what they have noticed; they are usually responsible for cleaning up birds that have died after hitting glass and may be great allies who help you collect data or convince building managers of the danger to birds.

After documenting the problem, review the window solutions on ABC's site, contact the building owner or manager to tell her or him about the problem, and provide advice or resources (such as this blog) on how to address it.

Keep in mind that you are making a request and looking for a partner to save birds, so be sure to keep these interactions positive and non-confrontational. Avoid vilifying the responsible party for a collision problem that they likely had no idea existed.

You can also talk to people who live, work, or shop in the building in question to see if anyone else shares your concerns. If so, ask them if they would like to be involved. By working with others, you build a collective voice that can draw more attention to the problem.

Remember, there are many ways to get involved. These include helping with monitoring, writing letters to building owners, attending meetings with building management, and organizing community action.

For more tips see our "How to Advocate for Retrofits" page.



Window imprint from bird collision. Photos by David Fancher

12) What can I do to keep buildings that harm birds from being constructed where I live?

Buildings designed without bird-friendly design principles have the potential to be deadly for birds.

A variety of factors determine the level of the threat they pose, including the amount of glass used, placement and reflectivity of the glass, the height and extent of vegetation around the building, and the presence of water, among other things.

Given incremental cost of constructing a bird-friendly building, we believe that all new buildings — not just glass-covered skyscrapers — should incorporate bird-friendly features. It is less expensive to incorporate these features from the beginning of the planning process, compared to retrofitting a building later.

There are several ways to help make this happen. The first is to develop and pass a local ordinance requiring the adoption of bird-friendly building standards in your community. To download an easy-to-use ordinance template, click here. You can also take a look at our list of existing ordinances mandating bird-friendly design or creating voluntary standards.

Keep in mind that ordinances tend to apply to large buildings and exempt low rises and homes, so it is important to make sure that the ordinance applies to as many buildings as possible.

Although passing an ordinance is a great accomplishment, it's not the only thing you can do.

Consider approaching the developers of new and proposed building projects with your concerns. Since this can be a time-consuming process, we suggest focusing on projects with a high likelihood of success (e.g., nature centers, museums) or organizations that influence multiple buildings (e.g., local government, universities, health care organizations, and architecture firms) to help them adopt bird-safe building policies.

While it's critical to make sure that new buildings incorporate bird-friendly designs, don't forget that existing buildings already account for hundreds of millions of bird deaths annually. Consequently, the need to retrofit homes and other buildings will remain an important way to reduce bird collisions for the foreseeable future.

To learn more visit our "Creating Bird-Friendly Legislation" page.



Bird-friendly building design can improve a building's appearance while reducing bird deaths. Photo by Almere

1. Loss, Scott R., Tom Will, Sara S. Loss and Peter P. Marra. 2014. Bird–building collisions in the United States: Estimates of annual mortality and species vulnerability. Condor 116:8-23. https://doi.org/10.1650/CONDOR-13-090.1
2. Loss S.R., Will T., and Marra P.P. 2013. The impact of free-ranging domestic cats on wildlife of the United States. Nature communications 4(1):1-8. https://doi.org/10.1038/ncomms2380
3. Klem, D., Jr. 1990. Bird injuries, cause of death, and recup with windows. Journal of Field Ornithology 61(1):115- 119. https://www.jstor.org/stable/4513511

4. Samuels B, Fenton B, Fernández-Juricic E, & MacDougall-Shackleton SA. 2022. Opening the black box of bird window collisions: passive video recordings in a residential backyard. PeerJ 10:e14604 https://doi.org/10.771 J4
5. Kummer, J. A., C. J. Nordell, T. M. Berry, C. V. Collins, C. R. L. Tse, and E. Bayne. 2016. Use of bird carcass removals by urban scavengers to adjust bird-window collision estimates. Avian Conservation and Ecology 11(2):12. http://dx.doi.org/10.5751/ACE-00927-110212
6. Riding, Corey S. and Scott R. Loss. 2018. Factors influencing experimental estimation of scavenger removal and observer detection in bird–window collision surveys. Ecological Applications 28(8): 2119-2129. https://doi.org/10.1002/eap.1800
7. Hager, Stephen B., Bradley J. Cosentino and Kelly J. McKay. 2012. Scavenging effects persistence of avian carcasses resulting from window collisions in an urban landscape. J. Field Ornithol. 83(2) 203-211. https://doi.org/10.1111/j.1557-9263.2012.00370.x
8. Parkins, Kaitlyn L, Susan B. Elbin and Elle Barnes, 2015. Light, glass, and bird–building collisions in an urban park. Northeastern Naturalist 22(1): 84- 94. http://dx.doi.org/10.1656/045.022.0113
9. Bracey, Matthew A. Etterson, Gerald J. Niemi, and Richard F. Green. 2016. Variation in bird-window collision mortality and scavenging rates within an urban landscape. The Wilson Journal of Ornithology 128(2):355-367. https://doi.org/10.1676/wils-128-02-355-367.1
10. La Sorte FA, Fink D, Buler JJ, Farnsworth A, and Cabrera-Cruz SA. 2017. Seasonal associations with urban light pollution for nocturnally migrating bird populations. Glob Change Biol. 23:4609–4619. https://doi.org/10.1111/gcb.13792
11. McLaren, J. D., Buler, J. J., Schreckengost, T., Smolinsky, J. A., Boone, M., Emiel van Loon, E., Dawson, D. K. and Walters, E. L. 2018. Artificial light at night confounds broad-scale habitat use by migrating birds. Ecol Lett. 21(3):356-364. https://doi.org/10.1111/ele.12902
12. Van Doren, Benjamin M., Kyle G. Horton, Adriaan M. Dokter, Holger Klinck, Susan B. Elbin and Andrew Farnsworth. 2017. High-intensity urban light installation dramatically alters nocturnal bird migration. Proc Nat Acad Sci: 114 (42) 11175–11180. https://doi.org/10.1073/pnas.170857411
13. Van Doren, Benjamin M., David E. Willard, Mary Hennen, Kyle G. Horton, Erica F. Stuber, Daniel Sheldon, Ashwin H. Sivakumar, Julia Wang, Andrew Farnsworth, and Benjamin M. Winger. 2021. Drivers of fatal bird collisions in an urban center. PNAS 118(24):e2101666118. https://doi.org/10.1073/pnas.2101666118
14. Korner, P., von Maravic, I. and Haupt, H. Birds and the 'Post Tower' in Bonn: a case study of light pollution. J Ornithol 163, 827–841 (2022). https://doi.org/10.1007/s10336-022-01985-2
15. Gelb, Y. and N. Delacretaz. 2006. Avian window strike mortality at an urban office building. Kingbird 56(3):190-198. https://nybirds.org/KBsearch/y2006v56n3/y2006v56n3p190-198gelb.pdf
16. Hager SB, Craig ME. 2014. Bird-window collisions in the summer breeding season. PeerJ2:e460. https://dx.doi.org/10.7717/peerj.460
17. Kahle LQ, Flannery ME, and Dumbacher JP. 2016. Bird-window collisions at a west-coast urban park museum: Analyses of bird biology and window attributes from Golden Gate Park, San Francisco. PLoS ONE 11(1): e0144600. https://doi.org/10.1371/journal.pone.0144600
18. Riding, C.S., O'Connell, T.J. & Loss, S.R., 2021. Multi-scale temporal variation in bird-window collisions in the central United States. Scientific Reports 11(1):1-12. https://doi.org/10.1038/s41598-021-89875-0
19. Borden, W.C., O.M. Lockhart, A.W. Jones and M.S. Lyonn. 2010. Seasonal, taxonomic and local habitat components of bird-window collisions on an urban campus in Cleveland, OH. Ohio J Sci 110(3):44-52. https://kb.osu.edu/handle/1811/52787
20. Scott KM, Danko A, Plant P, Dakin R. 2023. What causes bird-building collision risk? Seasonal dynamics and weather drivers. Ecology and Evolution 13(4):e9974. https://doi.org/10.1002/ece3.9974
21. Brown B.B., L. Hunter, and S. Santos. 2020. Bird-window collisions: different fall and winter risk and protective factors. PeerJ 8:e9401 https://doi.org/10.7717/peerj.9401
22. De Groot, Krista L., Porter Alison N., Norris Andrea R., Huang Andrew C., Joy Ruth. 2021.Year-round monitoring at a Pacific coastal campus reveals similar winter and spring collision mortality and high vulnerability of the Varied Thrush, Ornithological Applications 123(3):duab027. https://doi.org/10.1371/journal.pone.0144600
23. Dunn, E. H. 1993. Bird mortality from striking residential windows in winter. Journal of Field Ornithology 64(3):302-309. https://www.jstor.org/stable/4513821

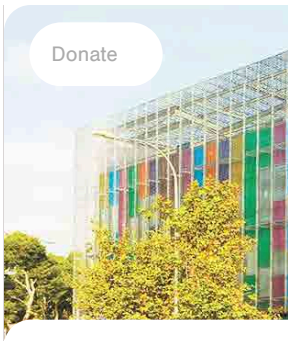
Related Products & Resources



Advocating for Bird-friendly Policies in Your Community

Learn how you can champion legislation to prevent window collisions and help birds in your community with resources from American Bird Conservancy.

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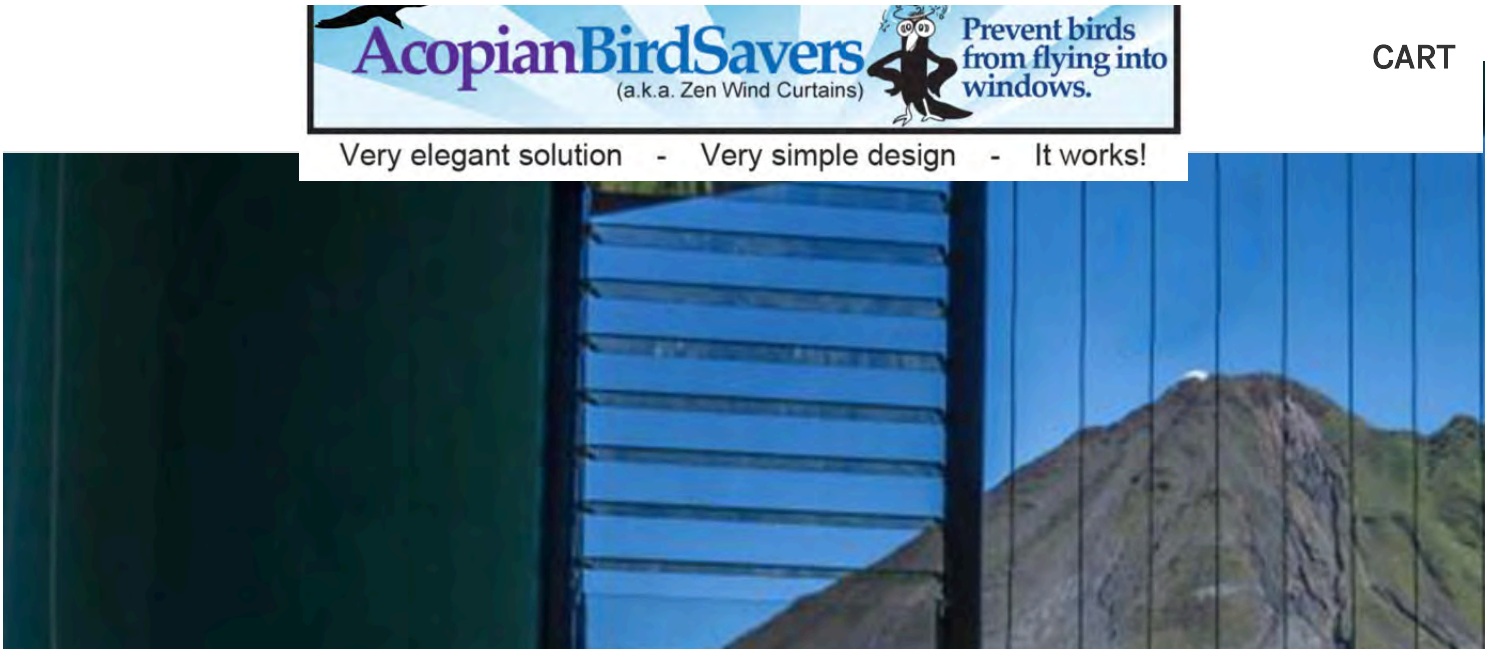
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CART



Prevent birds from flying into windows.

Zen Wind Curtains are a Simple Way to Save Birds

- Buy Acopian BirdSavers
- Make Acopian BirdSavers

- And it works!

Order BirdSavers | Make BirdSavers (DIY)

(a.k.a. Zen Wind Curtains)

"Forget about the fact that they save birds. They just look cool."

Why do birds sometimes fly into glass?



"Hummingbirds were always flying into a big picture window at our mountain house. Since installing the BirdSavers we haven't had any fly into the window."

-- Diane B., Mineral Bluff, GA
(BirdSavers in place for 7 months.)

[See all 140 user comments about BirdSavers here]



"The BirdSavers are on every window of our passive solar house, all 17 of them. BirdSavers are truly just that -- they save birds! We had multiple fatal strikes every year until we installed these marvellous cords. Swallows, starlings, kingbirds, sparrows, finches, even a pheasant. We were heartbroken with every one and tried everything we could find: decals, CDs hung on fishing line, mylar streamers. Nothing worked. But BirdSavers do! We have had them for over 4 years now and have had no bird strikes! We couldn't be more pleased with the way they work, the way they look, the easy installation and everything about them. BirdSavers are miraculous -- they do what they promise and do it simply and easily. We encourage everyone to "stop the thuds" and install Acopian Birdsavers. The birds will thank you! I believe in every word I wrote and we will always be grateful to Acopian BirdSavers. Thanks, Jeff!"

-- Lynn Walker, Ritzville, WA



"After three years of increasing problems with orioles, cardinals and robins hitting our windows, I came across the Acopian website. I followed the directions and made Zen Wind Curtains for seven of our windows.... easy to make and attach. What a difference they have made. Since they have been up, we have had no deaths of birds flying into the windows. The BirdSavers do not interrupt our views. Cleaning windows is easy, and does not require removal. We have had the curtains in place now for several years, and have shared the BirdSavers web site with other interested friends. They are a great solution... and such an easy solution, if only people knew about them. I am also impressed that while the site also sells the curtains pre-made, the instructions to "make your own" are shared for free, and are so easy to follow, so as to make them readily available. Acopian BirdSavers is a successful, inexpensive and attractive answer to help save our winged friends!"

-- BirdSavers DIYer, Iowa

See all 140 user comments about BirdSavers here

"The BirdSavers are on the outside of large sunroom windows. A bird feeder is about 25 feet away. Before I put the BirdSavers up I was going to take the feeder down as too many birds hit the sunroom windows. The BirdSavers were installed three years ago or so and not one bird has hit my windows since then. None. They are amazing. I am totally satisfied with the results. They resulted in NO Bird strikes for over three years. They also look good on the Windows. We barely see them when we look out the windows in our sun room. I highly recommend this product to everyone who wants to prevent bird deaths from strikes."

-- Peggy Brennan, North Haven, CT
(BirdSavers in place for 2 years, 11 months.)

See all 140 user comments about BirdSavers here





Some quick and simple measurements are all that are needed for you to order custom hand-made, cool looking Acopian BirdSavers for your windows! Or use our simple instructions to make DIY BirdSavers yourself.

"Acopian BirdSavers offer a practical and effective way to reduce window kills. I recommend them wholeheartedly."

-- Keith L. Bildstein, Ph.D.
Professional Ornithologist and Conservationist

A Simple Way to Save Birds!

When people think of bird mortality they usually think of cats, wind turbines, and pesticide poisoning, among other causes. In fact, in North America the largest number of birds are killed each year by glass!

Listen to BirdSavers on the radio:

- NPR's You Bet Your Garden show
- Laura Erickson's For The Birds show

Scientific paper downloads about Acopian BirdSavers (PDF):

- "Evaluating the Effectiveness of Acopian BirdSavers to Deter or Prevent Bird-Glass Collisions" by Dr. Daniel Klem, Jr.

Acopian BirdSavers can be used to comply with the "LEED Credit Pilot 55 - Bird Collision Deterrence". Prevent birds from flying into windows.

Please print and display (or handout) any of these

BirdSavers materials if you want people to know about this easy, elegant, inexpensive technique to prevent birds from dying at our windows.

AcopianBirdSavers (a.k.a. Zen Wind Curtains) Prevent birds from flying into windows.

CART

Very elegant solution - Very simple design - It works!

AcopianBirdSavers

Prevent birds from flying into windows.

- Very elegant solution.
- Very simple design.
- It works!



www.BirdSavers.com

See what bird experts and users have to say.

Learn How to Make Your Own (DIY)

Buy Online

Acopian BirdSavers • 131 Loomis Street • Easton, PA • 18045 • Phone: 610-258-6149



Very elegant solution - Very simple design - It works!

major problem s this design, they will be convinced that it should be at the top of anyone's arsenal of techniques who desires to easily prevent bird¬-window collisions. A vast majority of people who have Acopian BirdSavers on their windows or have seen Acopian BirdSavers on windows, if they even notice them, admire the aesthetic look of them. And people who have them on their windows are happy to not be killing birds anymore.

I feel great satisfaction when BirdSavers are used because house or building aesthetics are not compromised, birds are being saved, and people are happy with the results.

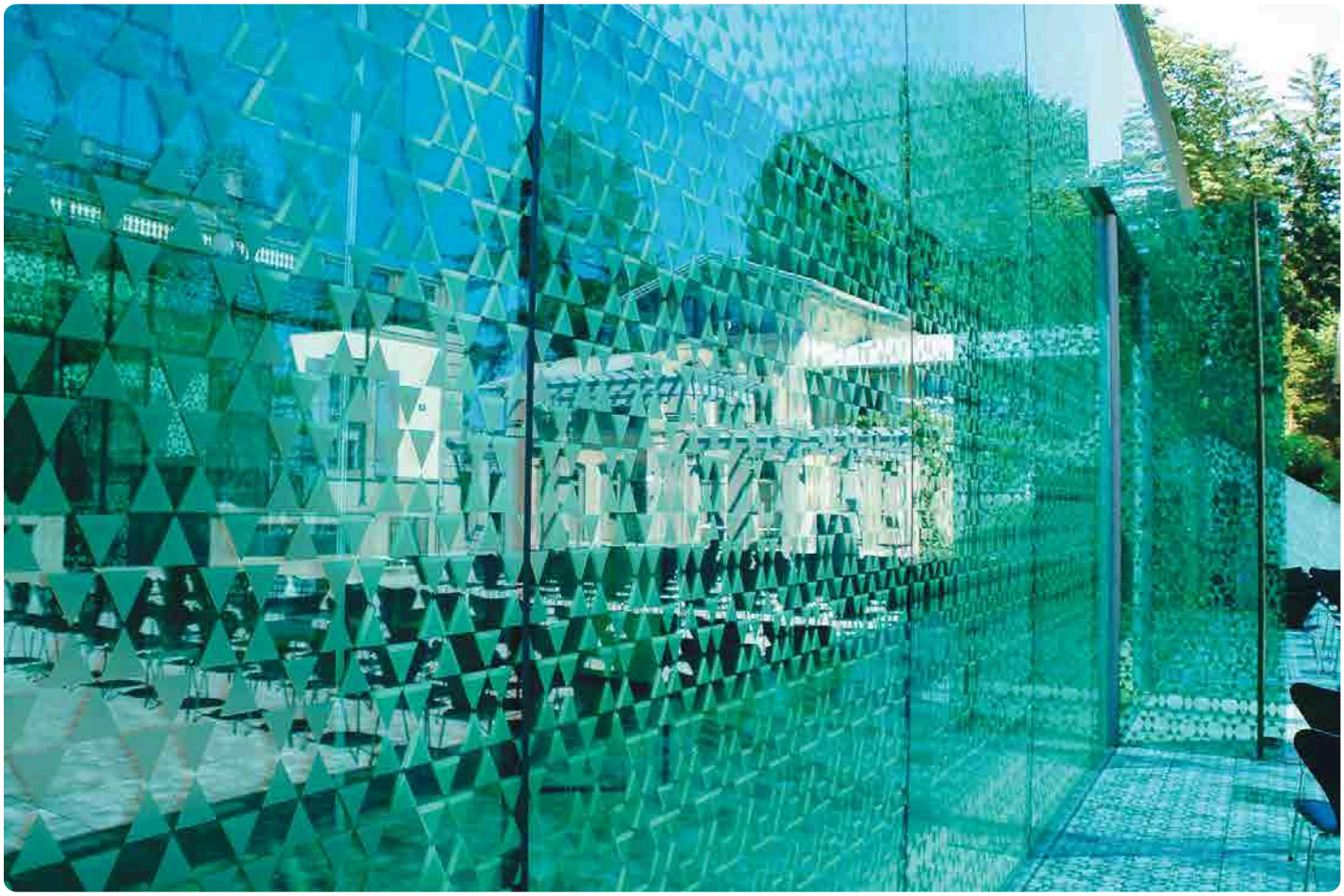
- Jeff Acopian
Easton, Pennsylvania

Acopian BirdSavers
131 Loomis Street
Easton, PA 18045

Phone: (610)258-6149
dizzybird@birdsavers.com

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Products



Museum Rietberg in Zürich. Photo by Hans Schmidt.

About this Products Database

No product can be guaranteed to stop all collisions in real world conditions. Glass can vary in appearance from one façade of a building to another or with time of day, depending on solar angle, reflected environment and other factors.

The Threat Factor[tm] number is determined under standard conditions and does not capture that variety. Instead, Threat Factor is a relative index, and products with lower TFs are considered more effective at preventing collisions. A TF of 30 suggests that collisions will be reduced by at least 50 percent and is ABC's upper threshold for recommending a product.

Products with UV patterns should be considered carefully for some applications: Materials with ultra-violet patterns will vary in effectiveness with the amount of UV light present. This means that when the UV index is low – under low light conditions in early morning or evening or if the glass is shaded, or when it is overcast Skip to main content less visible to birds. In addition, not all types

of birds can see UV. For example, songbirds can see UV, raptors and pigeons cannot. Because Threat Factors can be effected by lower coatings, published Threat Factors apply only to the glass assembly tested.

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Search Criteria

Are you a building professional or interested in home windows?

–Choose One–

1 - 10 of 229 results



Paint: Oil-based Pen

Any

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Image drawn on outside of window, using oil-based pen

Marker Type: Paint Pattern

Show More



Window Alert Decals (multiple styles) 2×2″ spacing recommended

Window Alert

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Recommend installation with 2" x 2" spacing

Marker Type: Decal

Product Line: WindowAlert

Show More



Glass: stained

Any Stained Glass

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

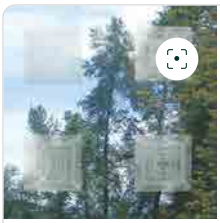
Prescriptive rating

Marker Type: Low Reflection

Skip to main content

American Bird Conservancy

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Bird’s Eye View

Artscape Inc.

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Non-adhesive, easy to apply and remove; 2x2" spacing recommended. Although field tested on the inside surface by Dr. Daniel Klem, this was on uncoated window glass. ABC recommends them on the exterior surface only.

Marker Type: Decal

Product Line: Bird's Eye View

Show More



Decals: bird silhouettes

Wandkings

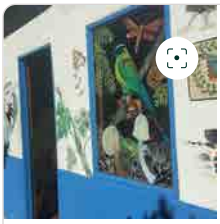
Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Place decals using 2"x2" spacing guidelines

Marker Type: Decal

Product Line: Bird and Window Protection Stickers

Show More



Paint: Tempera

Any

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Use non-toxic paint to put up pattern or picture using 2x2" spacing guidelines

ABC Approved: Yes

Marker Type: Paint Pattern

Show More



Paint: Acrylic

Any

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Use non-toxic paint to put up pattern or picture using 2x2" spacing guidelines

Marker Type: Paint Pattern

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Solar Siding

Mitrex

Threat Factor: 1

ABC Approved: Yes

Marker Type: No Reflection

Product Line: Solar Siding

Show More



Wood

Threat Factor: 1

Any wood without reflective paint

ABC Approved: Yes

Marker Type: No Reflection

Show More



Vinyl

Threat Factor: 1

any vinyl that is not reflective

ABC Approved: Yes

Marker Type: No Reflection

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1 2 3 ... 23 Next »

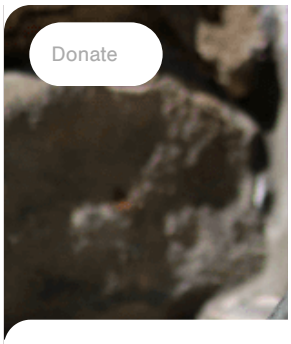
Related Strategies for Glass Collisions



Frequently Asked Questions About Birds and Glass

Glass collisions kill vast numbers of birds in the United States each year. Yet most Americans know little about this danger, and even fewer are aware of the solutions available to help prevent these deaths — fixes that in many cas...

Learn More



Existing Bird-Fri

Many municipalities have en
window collisions. American

Learn More

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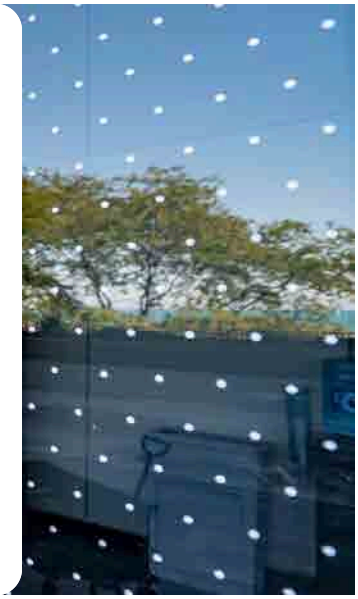


FEATHER FRIENDLY Evolution™

Feather Friendly Large-Format Pro

Our top-of-the line large-format product now features **Feather Friendly Evolution™**, a material that will redefine bird-glass collision mitigation

Take Action



FeatherFriendly Evolution™

Bird Safety. Redefined

What Sets Feather Friendly Evolution Apart from Other Materials

Unmatched Durability

Lasts 20+ years – that's over 40 bird migration cycles!

PFAS-Free

Manufactured without Per- and Polyfluoroalkyl Substances (PFAS), supporting a more sustainable choice for the environment.

Low Environmental Footprint

Long lifespan reduces waste and the need for frequent replacements.

Quality Commitment

Supported by a 15-year warranty, showcasing our dedication to longevity

Expanded Installation Range

Can be installed in temperatures as low as -20°C, allowing for year-round installation, even in colder climates

Learn More



Color Options:

White | Light Grey | Dark Grey | Black

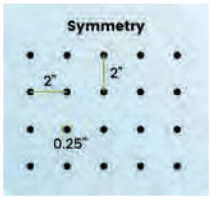
The Feather Friendly Edge

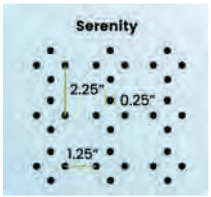
- **Tested and approved by American Bird Conservancy, Dr. Daniel Klem Jr. Recommended by conservation organizations and environmental advocacy groups worldwide.**
- **Bird collisions reduced by over 95%, demonstrated by independent studies and real-world results.**
- **Variety of patterns and colours that are customizable to any project size and need.**
- **No thermal load - markers are not full film and cover minimal glass surface**
- **Meet & exceed published bird-safe standards and guidelines worldwide.**
- **Large, authorized dealer-applicator network across North America and beyond.**

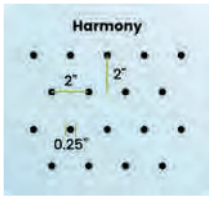
American Bird Conservancy | Dr. Daniel Klem Jr. | USGBC MEMBER

Ten Standard Patterns

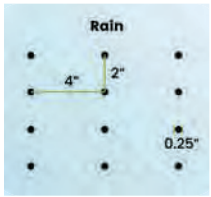
Choose from 10 standard patterns or make your project unique with endless customizable designs and colors

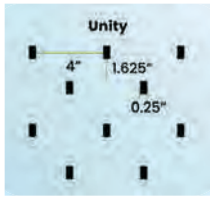


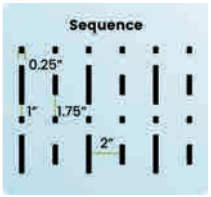


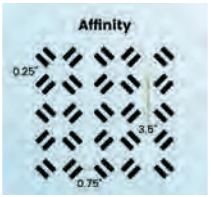


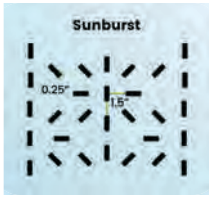


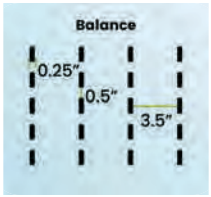












Download Spec Sheet (PDF)

Past Projects, Same Expertise

Explore our past large-scale projects that paved the way for Feather Friendly Evolution













Testimonials

"The results are almost miraculous.""

★★★★★

David Willard



Make Your Glass Smarter and Safer

Remove all the guesswork! Our team is available for free consultation to help you chose the right solution for your project.

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Are you a lost bird? It looks like the page you're searching for can't be found right now. Let's get you back to your flight path...

Search ABCBirds.org...



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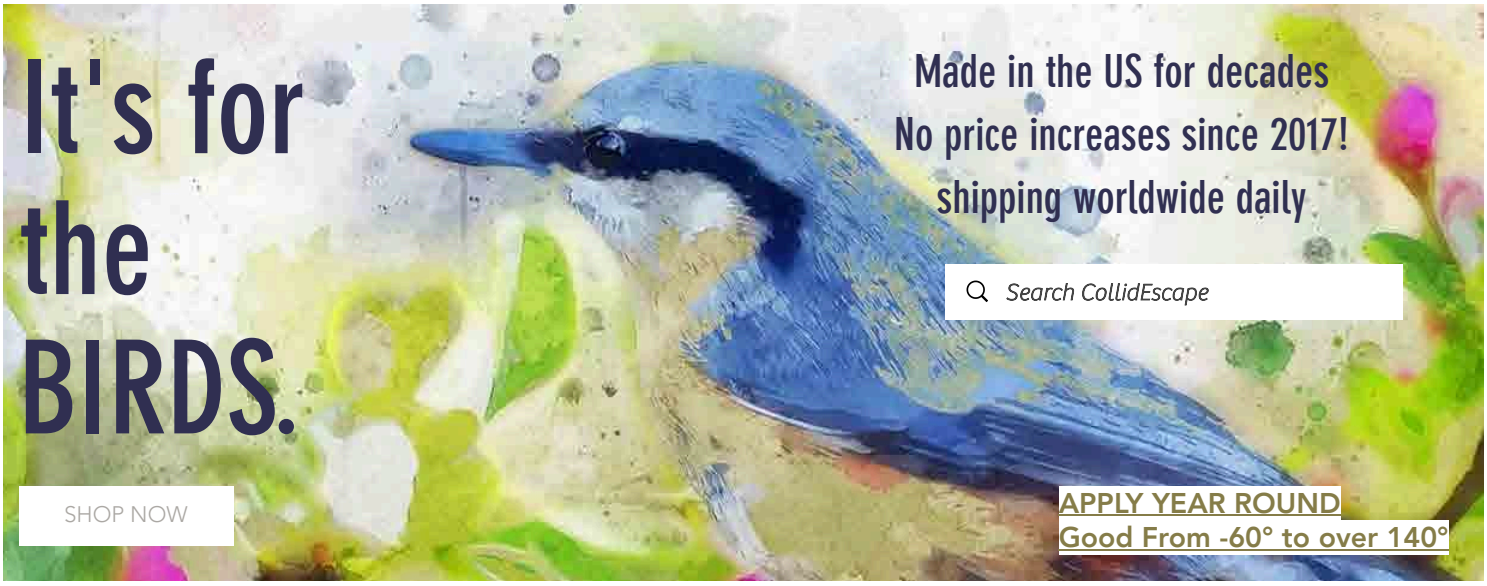
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View Commercial Options

Why do birds fly into glass?

Collisions are most commonly caused by the reflective characteristics of glass. Because the outside of glass reflects the environment around it, birds do not recognize it as a barrier. The birds see the reflected environment, such as trees and sky, and collide with the glass assuming it is a clear flight path. Any window, large or small can be a killer. CollidEscape is applied to the outside of a window so as to disrupt the reflection off the outside surface that birds perceive as a continuation of their environment.

Birds are frequently killed in these collisions or are stunned, only to die of internal injuries later. It is estimated that as many as *one billion* birds die as a result of window collisions every year in the United States alone.

ALL WE DO IS OFFER SOLUTIONS TO DISRUPT THE REFLECTION OFF THE OUTSIDE OF WINDOWS. PERIOD.

NO PRICE INCREASES SINCE 2017!

Prevent collisions with a
CollidEscape Guaranteed product:
WHITE * CLEAR * TINTED * IMAGED

Reduce collisions with a
CollidEscape High-Performance product.
PATTERNS * TAPE

film installation video is HERE!





SHOP NOW

CollidEscape GUARANTEED

White, tinted or imaged



ape High-Performance PATTERNS



NYC 2x2 Dot Pattern



Clear Tape

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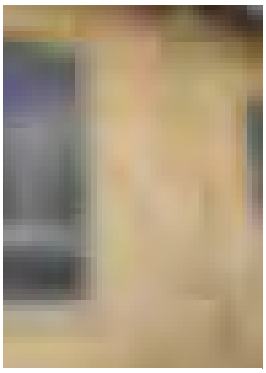
Why do birds attack windows?

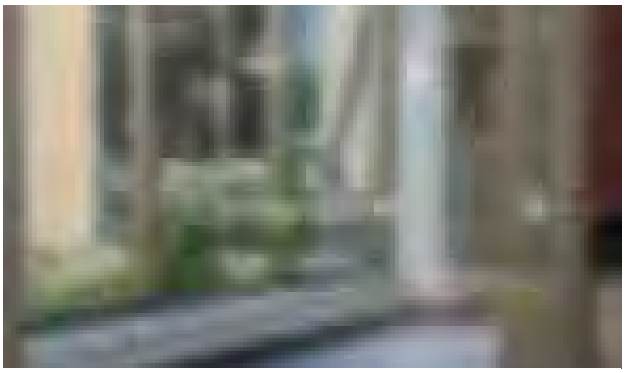
Birds see their own reflection in a window and attack the "intruder" in order to protect its territory. This is known as territorial aggression.

While this behavior is not generally harmful to the birds, it can be very aggravating to homeowners. Territorial aggression is most common during breeding and nesting seasons.

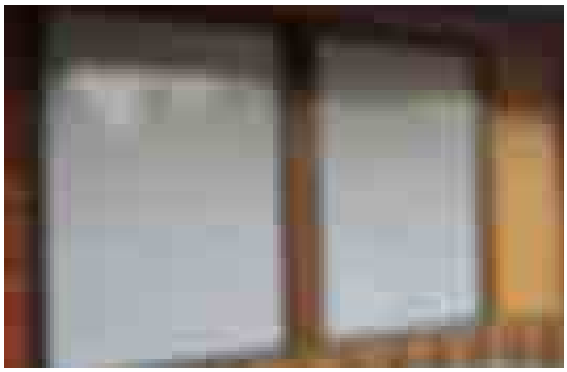
Prevent attacks due to territorial aggression by completely eliminating window reflections with a product designed to prevent territorial aggression.

The Territorial Aggression options

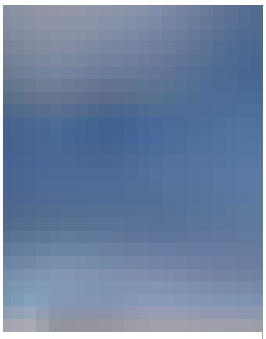




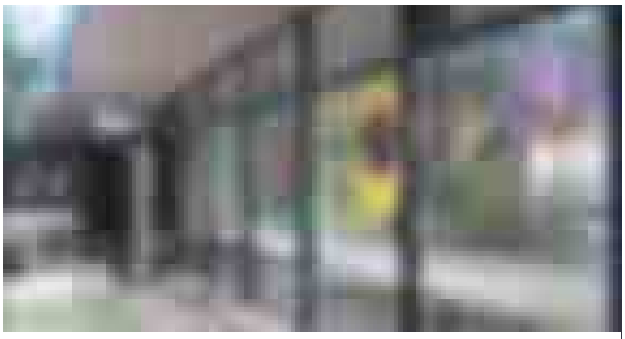
NYC 2x2 Dot Pattern



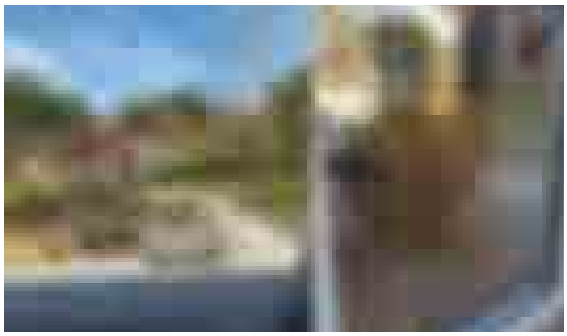
CE White - Guaranteed



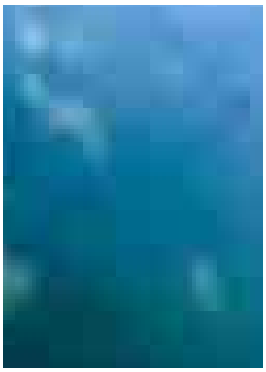
ed



CE Imaged - Guaranteed



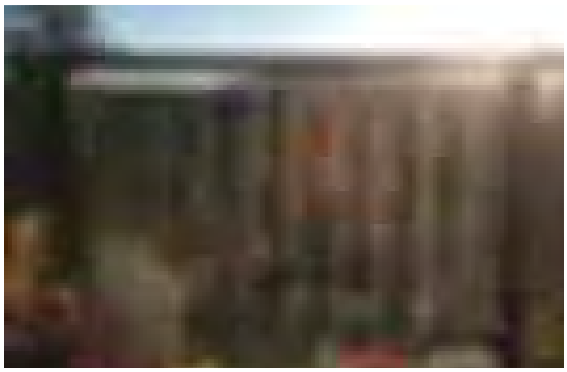
White Dot Patterns 2x4 High-Performance



nance



Patterns & Tapes - Budget



Clear Pattern Tape -High Performance

WHY WE DO WHAT WE DO:9/19/2019- WASHINGTON POST: North America has lost 3 billion birds in 50 years

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inquiry@CollidEscape.org

Preventing Glass Collisions

Carolina Wren at window. Photo by Kristi Blokhin, Shutterstock.

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Creating a Future Without Glass Collisions

Birds see the world differently than we do — it's part of what makes them extraordinary flyers and navigators capable of migrating thousands of miles in the dark. But they aren't equipped to handle the maze of reflective windows in multi-story buildings in our cities. Nor can they see the crystal clear glass used in homes, schools, stores, and other buildings. And although these structures are shorter, they pose the same threat to birds as the skyscrapers downtown. More than 1 billion birds die from collisions with glass every year in the U.S. alone. It's a problem of a staggering scale, but it's one we can solve together.

Solutions in Sight

ABC's Glass Collisions program is leading the way in finding solutions to this problem that plagues birds both common and rare throughout the year, wherever they are. We encourage systemic change, advocating for collision-reducing legislation, offering training for architects and developers, and empowering concerned individuals to push for change in their communities. We also provide education and practical support for implementing bird-friendly changes wherever you live and make it easy to find products and solutions for reducing collisions at home.

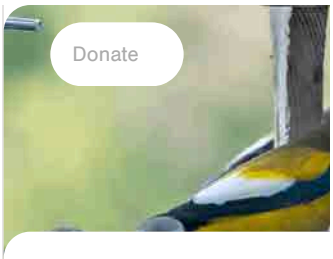
Together, we have the capacity to dramatically reduce the number of birds dying from glass collisions.



Frequently Asked Questions About Birds and Glass

Glass collisions kill vast numbers of birds in the United States each year. Yet most Americans know little about this danger, and even fewer are aware of the solutions available to help prevent...

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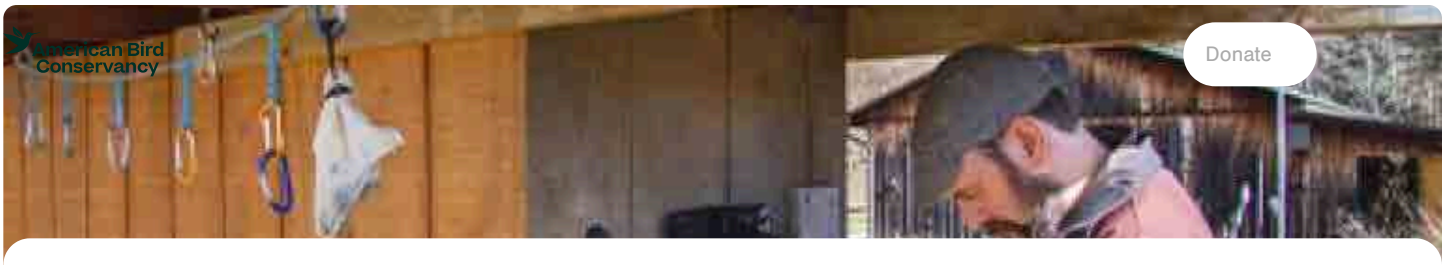
Products That Prevent Collisions

Looking for glass for a new building, or a solution to fix existing windows? Search our comprehensive material database to find the right product.

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Museum Rietberg in Zürich. Photo by Hans Schmidt.

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ABC Glass Testing and Research

Discover how American Bird Conservancy researches and tests bird-friendly glass and other solutions to prevent window collisions. ABC's rating system assigns a Threat Factor™ score that indicates which materials birds are most likely to avoid during our tunnel testing process.

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Meet the Glass Collisions Team

American Bird Conservancy

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ABC's Collisions Team carries out research to better understand the threat of window collisions, rigorously tests and evaluates products and solutions to prevent collisions, and supports change in communities through advocacy, education, and outreach.

Bryan Lenz
Glass Collisions Program Director Bird City Network Director

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Kaitlyn Parkins
Glass Collisions Program Coordinator

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Christine Sheppard
Glass Collisions Program Director

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Bird Collision Glass Testing Program Coordinator

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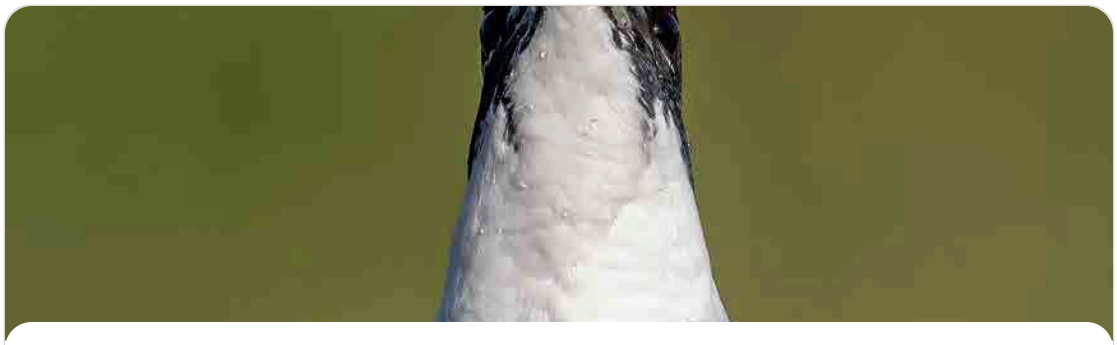
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ABC and partners work to restore the soaring forests with mature, tall trees, understories of young trees and shrubs, and open forest floor that represent ideal habitat for breeding Wood Thrushes. Photo by Som Prasad.

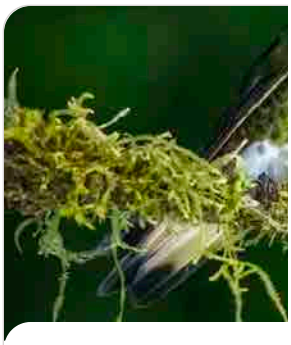
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Fisheries can be a major threat to seabirds, whether by overfishing or bycatch. Explore American Bird Conservancy's solutions to make fisheries safer for birds like albatrosses, shearwaters, and petrels.

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Creating and Ma

Birds are facing a suite of th
bird population declines. Hal

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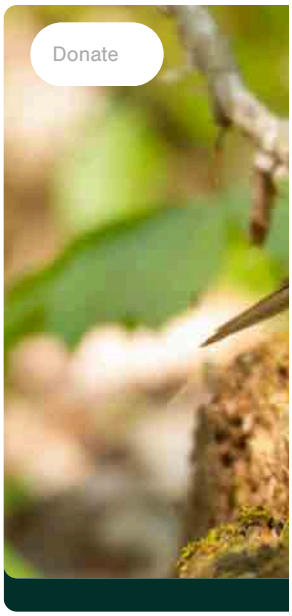
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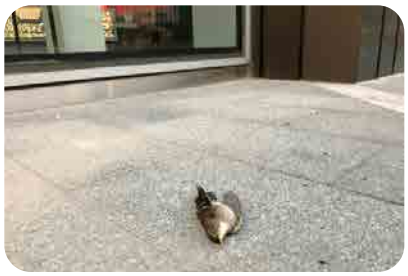
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Solutions for Homes

Find American Bird Conservancy's recommendations for preventing birds from colliding with glass windows at home, including DIY approaches and a variety of products for different price ranges.





Preventing Birds from Hitting Windows at Home

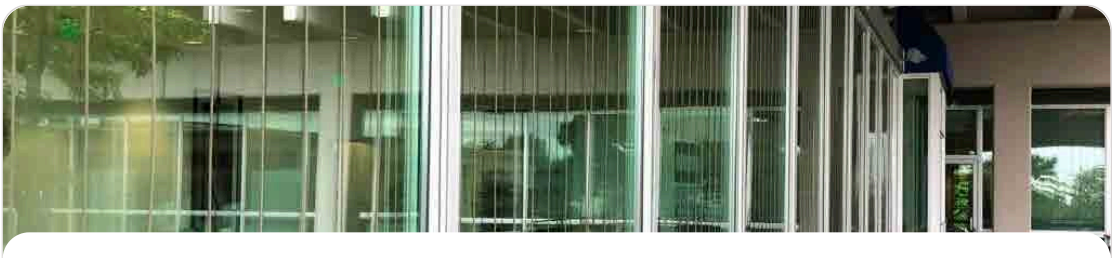
Birds can collide with windows anywhere: at home, at the office, at schools, or [illegible], almost half of all collisions take place at home. With more than one billion birds dying from window collisions each year in just the United States, the need to prevent collisions by making buildings safer is urgent. Here are ABC's recommendations for easy, effective, bird-friendly collision prevention solutions and answers to common questions about preventing window collisions at home.

If a bird has collided with your home, you are not alone — more than one billion birds die each year following window collisions in the United States. The good news is that there are many bird-friendly solutions available to fit a range of budgets (including no-cost options), and most can be installed easily. You can also enlist the help of a local repairperson, house painter, or window washer — it will be a quick job for them.

Common options for preventing window collisions include DIY approaches like placing insect screens on the outside of windows, using tempera paint to create patterns on the outside of windows, and applying decals. A number of bird-window collision prevention products are also available, including Acopian BirdSavers, Feather Friendly adhesive decals, Bird Crash Preventers, Solyx Bird Safety Window Films, Window Alert, and CollidEscape.

Three Simple Solutions to Prevent Bird Strikes

These inexpensive, easy-to-install products are proven to prevent bird strikes.



Acopian BirdSavers

Acopian BirdSavers are long-lasting hanging cords that can be in



Feather Friendly

Feather Friendly are durable
offers both DIY and professi

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Which Windows Should You Fix First?

For a bird-friendly home, start by identifying problem windows. Not all windows pose equal dangers to birds. In fact, the majority of collisions are often caused by a small number of problem windows. Identifying and fixing the most dangerous locations is a good way to prevent future collisions. To get started, treat the following windows:

- Windows that have already caused collisions.
- Large windows and glass doors, especially those that reflect habitat (including sky) or through which you can see sky or greenery.
- Windows across from bird feeders, bird baths, and fruit-bearing plants.

In many cases, fixing only these windows will stop almost all of your collisions. But remain vigilant: If collisions occur at other windows, you can apply similar solutions to continue making your home bird-friendly.

Where Do Bird-Friendly Window Products Go: Inside or Outside?

It may be tempting to place bird-friendly window products on the inside of windows, but this should be avoided whenever possible. Applied internally, the treatment is invisible to birds when window reflections outside are strong.

What About Hard-to-Reach Windows?

While ABC recommends applying all bird-friendly products on the outside of your windows, you might have windows that are hard to reach from the outside. A quick test can tell you if a solution on the inside of the window might work.

Begin by applying the proposed “inside” solution to your window. Then, observe the window from an outside location every two to three hours, starting in the early morning, to determine its visibility. If you can clearly see your test solution, birds might too. Your test solution should be something large and bright, like Post-It Notes, so that it has a chance to be visible through the reflections on the outside of the glass.

What Patterns and Colors Work Best to Prevent Collisions?

Research shows that most collisions can be prevented by applying patterns that are correctly sized and spaced on the outside of glass surfaces. Following these rules will make your treatment as effective as possible:

- Choose the right size pattern: If your pattern consists of stri Skip to main content : least one-eighth of an inch wide. If you use dots or similar shapes, they should be at least one-quarter of an inch in diameter. It is not necessary to use simple dots or

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stripes — any pattern that follows these rules will save birds.

- You should be able to see the pattern clearly from 10 feet away. This is important: Birds need to detect [illegible] om far enough away that they have time to change course and avoid a collision.
- Bigger is better: The larger the lines and dots are, the more effective they are as they become easier for birds to see. White patterns tend to perform best because they reflect the most light and provide greater contrast against a range of background colors and reflections.
- Space patterns correctly: Ideal spacing follows the two-inch-by-two-inch rule. Patterns that have vertical, horizontal, or diagonal spaces of two inches or less — and that follow the pattern size rules above — will prevent most collisions. Larger spacing poses a risk to small songbirds, including hummingbirds, that can easily fly through four-inch-wide gaps. Looking for an alternative? You can also apply a uniform solid pattern, including screens or solid-color window films, that covers the entire window.

Make New and Replacement Windows Safer for Birds

People often report large increases in collisions after replacing home windows. These are typically attributed to several causes, including:

- Increased reflectivity: New windows often have energy-efficient coatings and multiple panes of glass, both of which can make them more reflective than older windows.
- Reduced screen visibility: Window screens reduce reflections and prevent collisions; however, on newer windows, they are often sandwiched between panes of glass or may cover only the lower half of the window.
- Larger glass surfaces: New windows often lack the muntins and mullions — the “dividers” — needed to hold smaller pieces of glass, which also provide birds with visual cues that help prevent collisions.

Unfortunately, there aren’t many widely available bird-friendly options for new or replacement home windows on the market. However, there are several things you can do to make sure your new windows (and glass doors) are safe for birds:

- Install full external screens, even if the windows do not open.
- Apply one of the solutions discussed above to a new window.

You may be able to place a special order for one of the types of bird-friendly glass in ABC’s Solutions Database.

Additional Effective Products

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Bird Crash Preventers

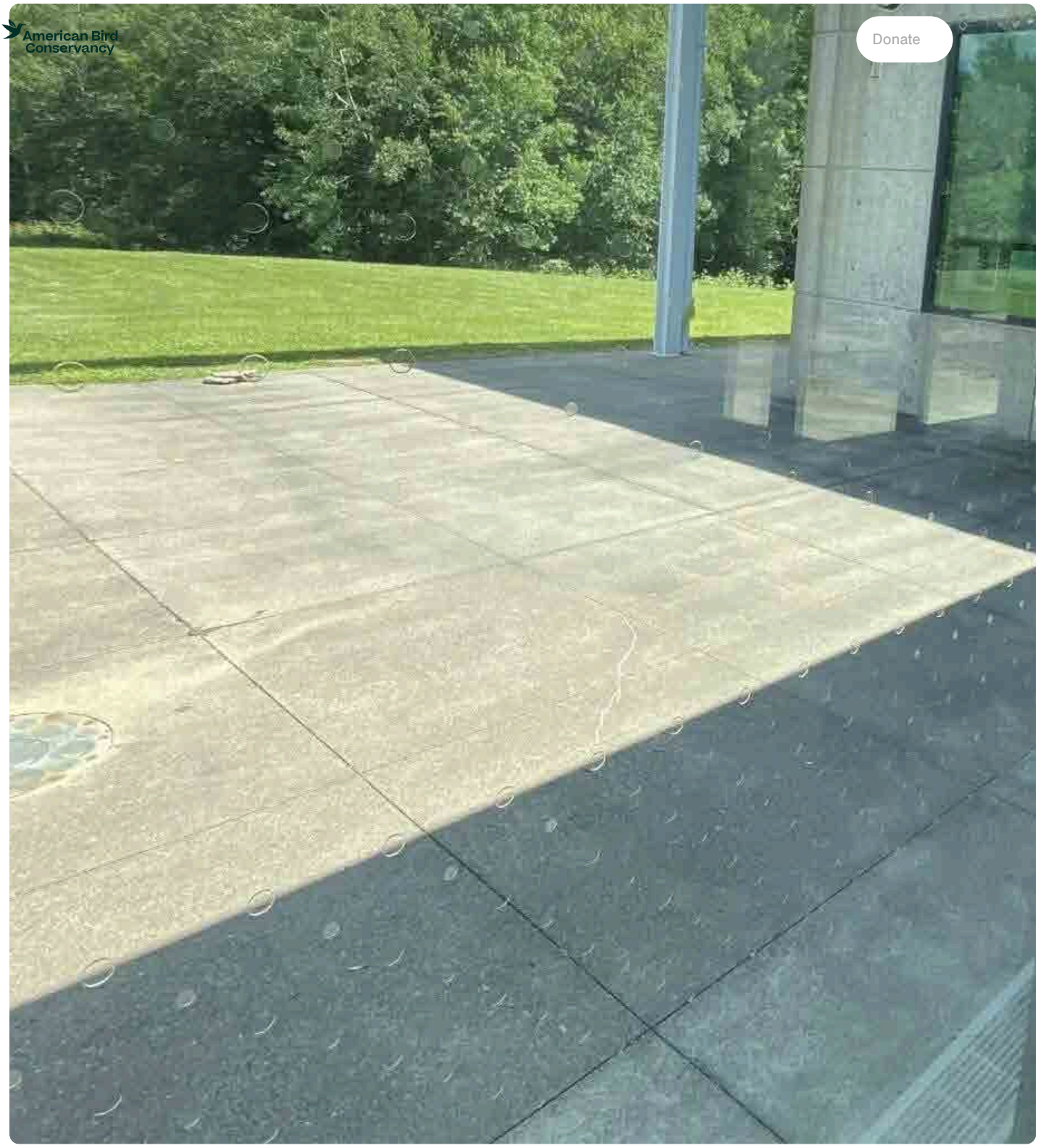
Vertical monofilament installed by screwing mounts into the outside of the building.

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Insect Screen

Installing standard-sized, commercially available screens can also help protect birds.



Bird Divert

Small, tightly-spaced translucent UV adhesive decals that work best on the outside of the window. Birds that don't see UV, like Mourning Doves, won't be protected but most songbirds should see this product. They offer both do-it-yourself and professional products.

Purchase

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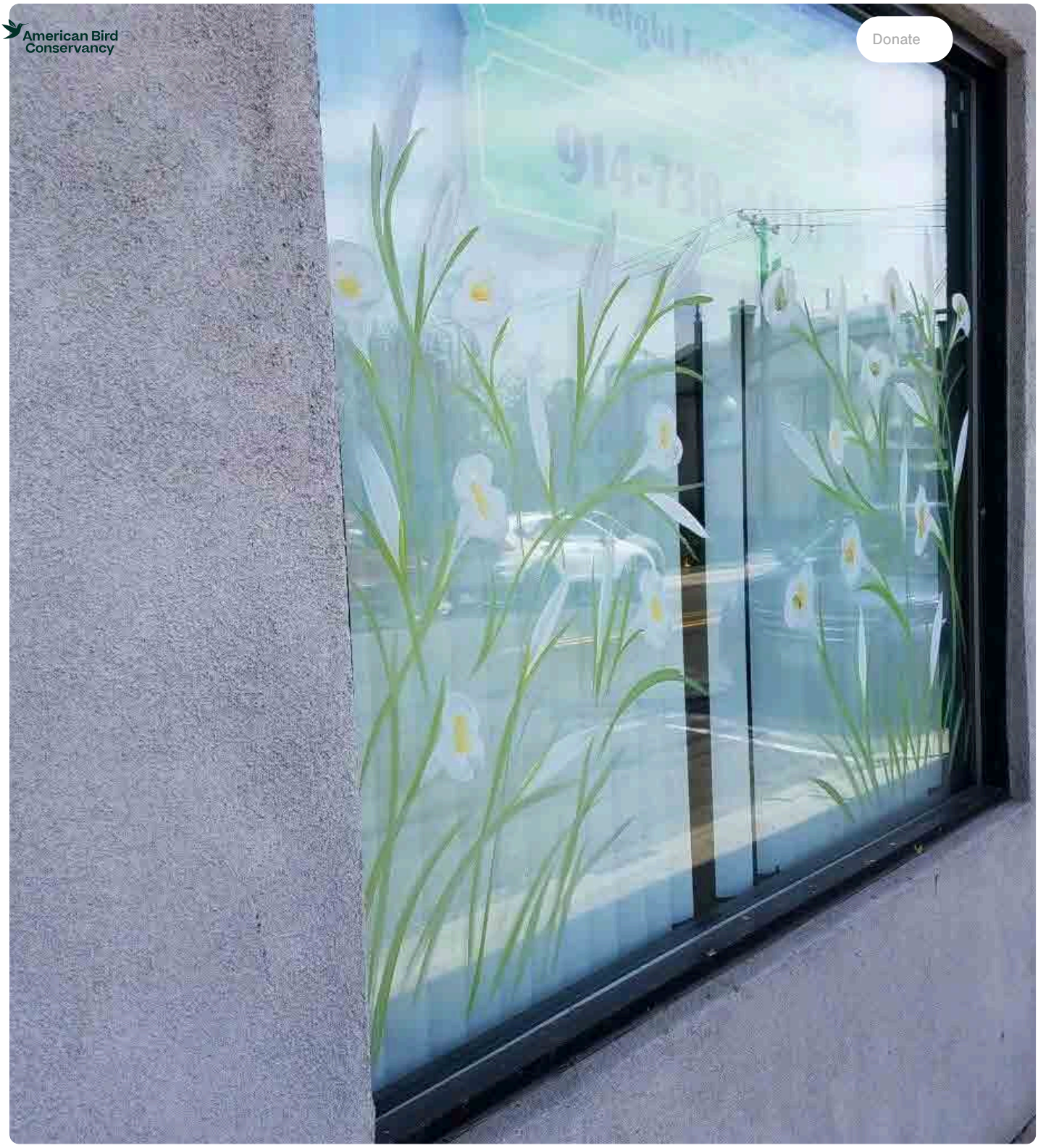


Solyx Bird Safety Window Film

Solyx offers six bird-friendly full-window films that might require professional installation.

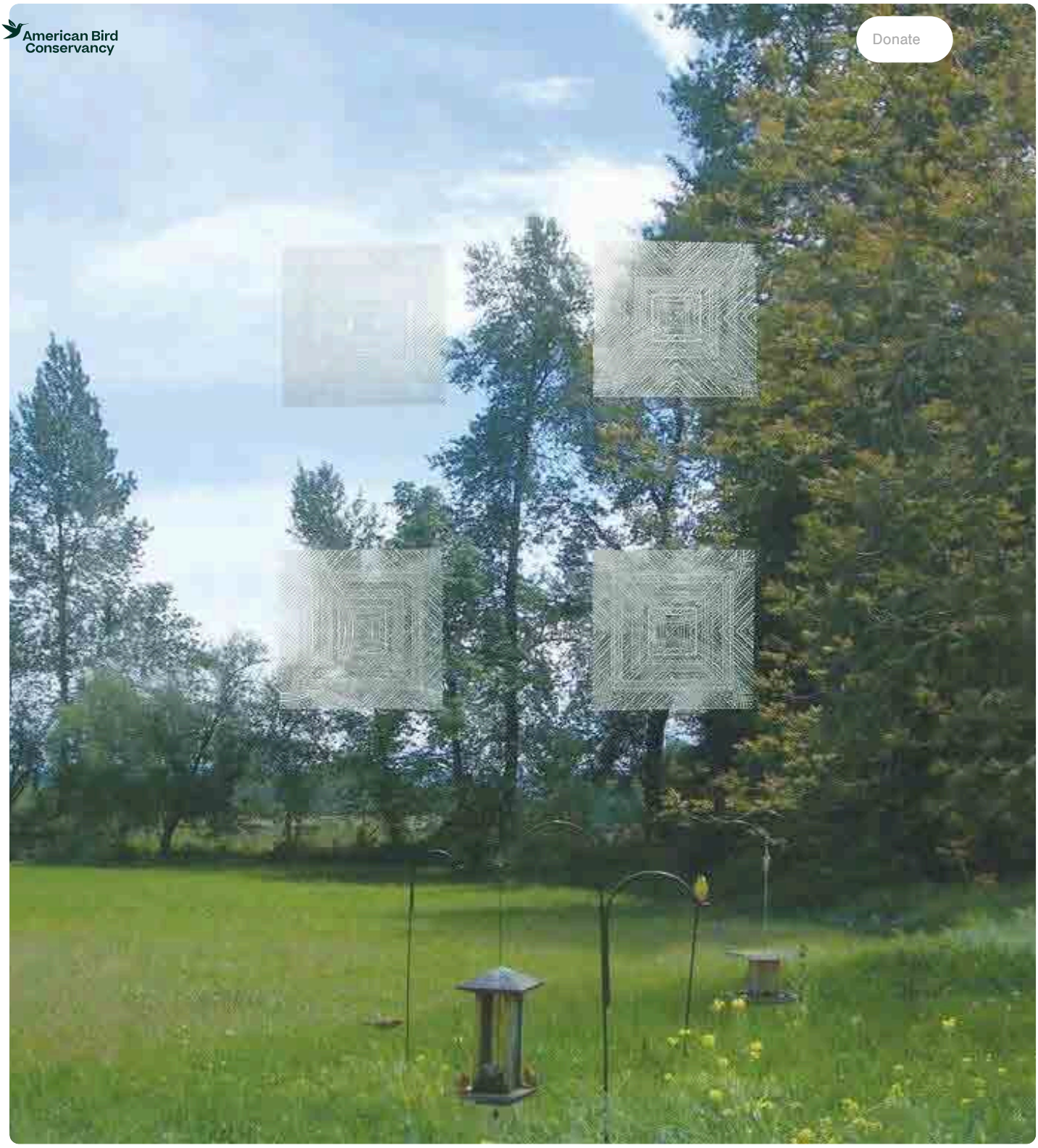
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Paint Your Own Design

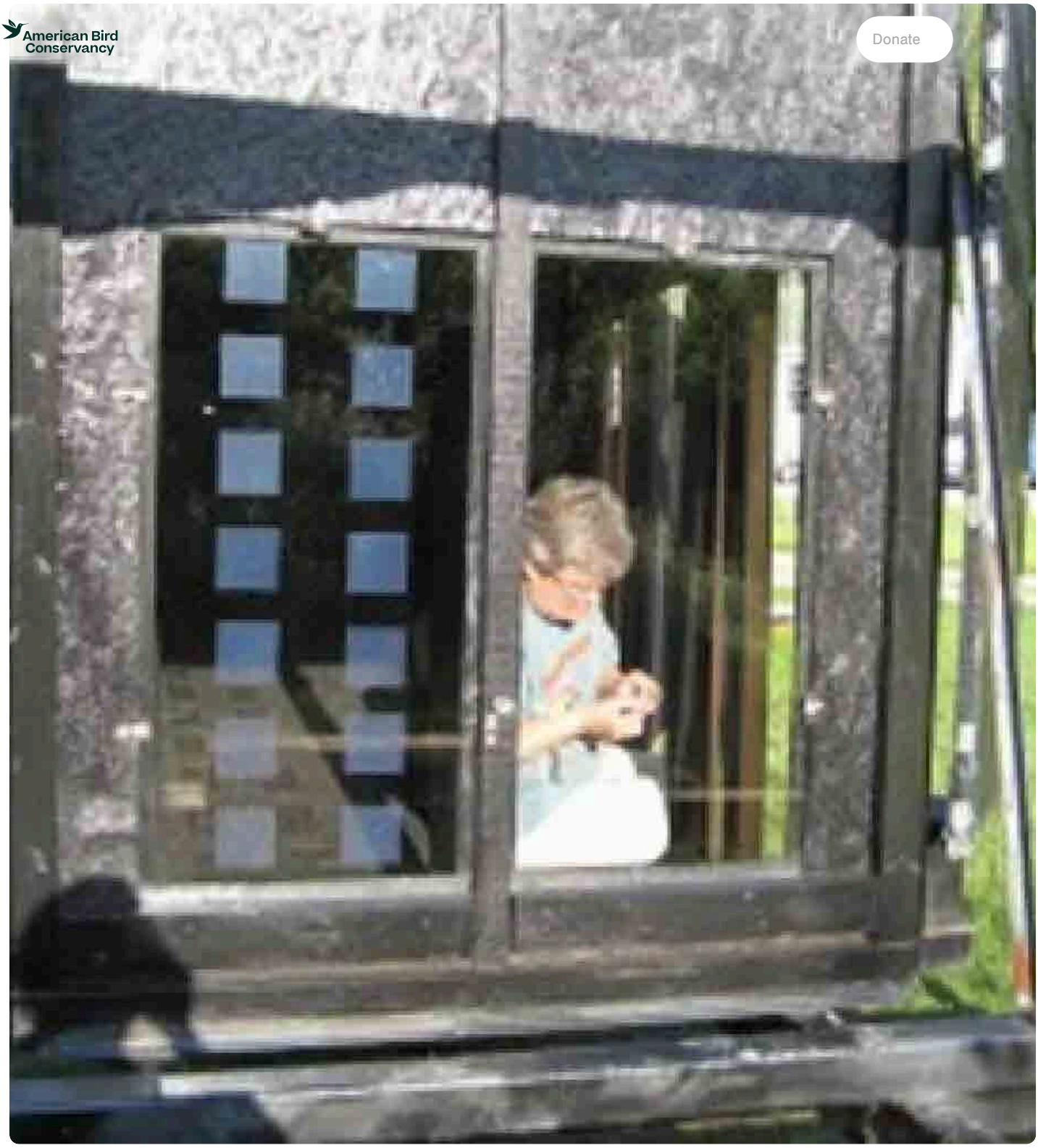
Use brushes/stencil rollers and non-toxic tempera paint, longer-lasting acrylic paint, or an oil-based pen. For this to be an effective solution, be sure to follow the pattern instructions below under “Ensure That Your Window Solutions Are Effective”



Bird's Eye View

Large translucent UV adhesive decals that work best on the outside of windows. Birds that don't see UV, like Mourning Doves, won't be protected but most songbirds should see this product. Decals should be closely spaced.

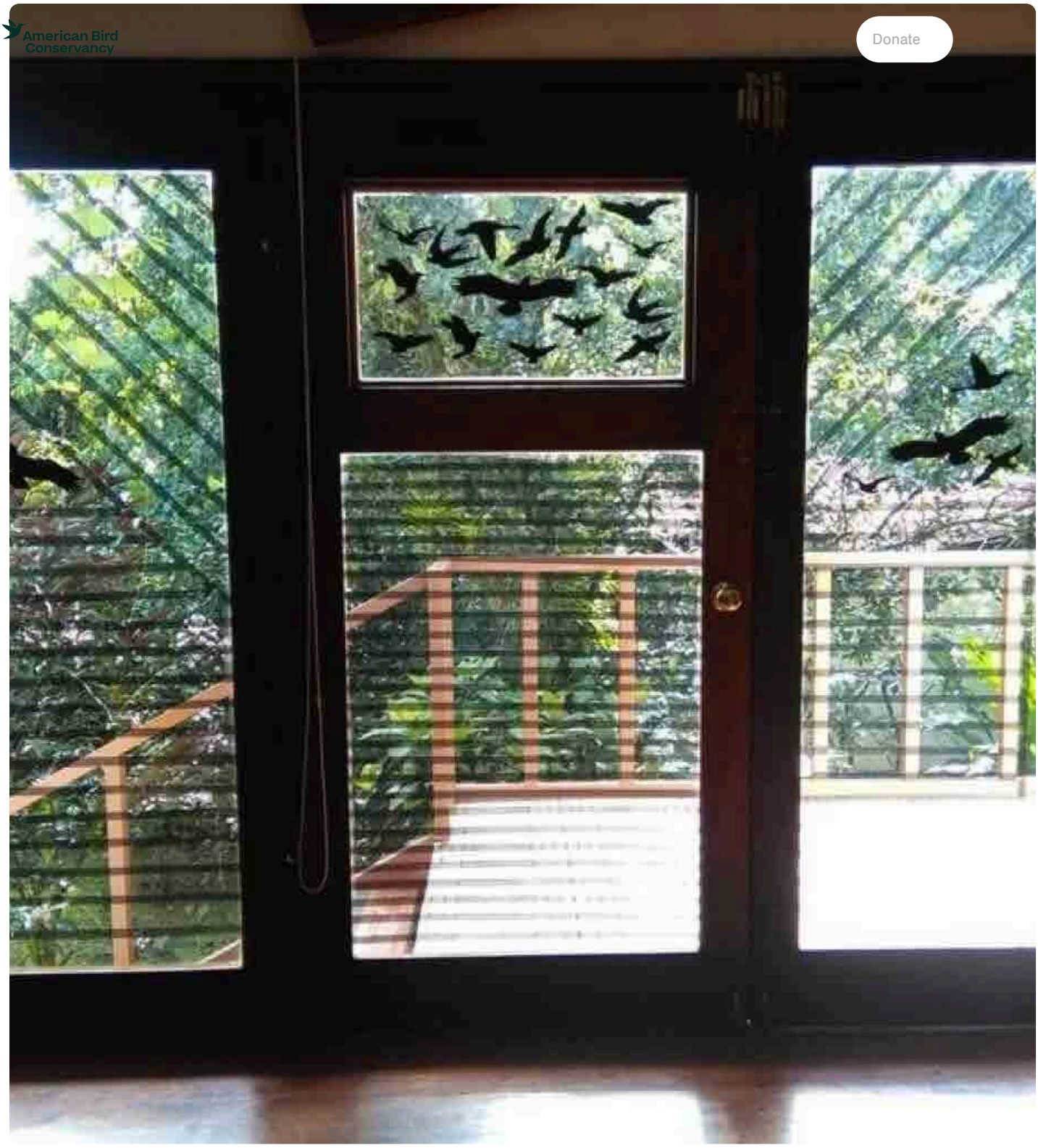
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Window Alert

Translucent UV adhesive decals that work best on the outside of the window. Birds that don't see UV, like Mourning Doves, won't be protected but most songbirds should see this product. Decals should be closely spaced.

Purchase



Decals

Decals on the outside of your windows that are at least one quarter-inch in diameter and spaced two to four inches apart should prevent most collisions. Many shapes and sizes available.

Purchase

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CollidEscape

CollidEscape sells many products as bird-friendly. ABC recommends full-window white CollidEscape.

Purchase

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Collisions Product Database

Visit the Collisions Solutions Center for a full breakdown of available products and methods for bird-friendly buildings for homes and other structures.

Explore Products

Museum Rietberg in Zürich. Photo by Hans Schmidt.

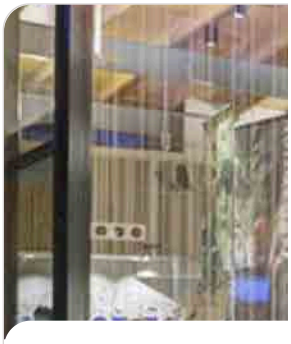
Explore More Collisions Solutions



Advocating for Bird-Friendly Building Retrofits

Find American Bird Conservancy's recommendations for preventing birds from colliding with glass windows on existing buildings and how to advocate for retrofits.

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About the ABC Rating System

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What is a Threat Factor?

It is difficult to objectively define what makes glass "bird-friendly." Although used frequently, the term 'bird-friendly' itself provides no specific guidance. Architects interested in designing a building that does not kill birds can select products for their insulation value, breaking strength, or a host of other characteristics, but until recently there was no system for specifying bird-friendly materials. Making analysis more difficult, the quality of being bird-friendly is more complex than a quality like insulation value because birds respond to the appearance of glass and this can vary dramatically for a single product as seen in the changing light of day, as well as under artificial light at night. Additional complexities such as IGU build, façade or freestanding installation, differing reflected environments and other factors make each situation unique. Contributing factors vary so much that an absolute measurement cannot be provided.

In 2010, experts from American Bird Conservancy and a team of architects interested in advancing the field of bird-friendly design developed the concept of Threat Factor (TF). This is a way to assign scores that provide a relative measure of how well materials with patterns of visual markers cause avoidance by birds in a standard, controlled test environment. These scores allow architects to use collision deterrence as a factor when designing buildings. The system also permits evaluation of products that can be applied to existing glass (retrofits). TFs also made it possible to create a credit for reducing bird collisions in the LEED rating system and have now begun to be included in legislation, like New York City's Local Law 15 of 2020.

Where Do Threat Factors Come From?

Ideally, Threat Factors could be derived from monitoring collisions on glass at a collection of diverse, existing buildings, replacing that glass with a product under review, continuing to

monitor to see whether collisions are reduced and calculating the reduction. Unfortunately, this type of data is very rare and this type of test would be very costly. It would also take years to acquire enough monitoring data to reliably detect a trend for a single product and, importantly, it would kill birds. ABC realized the need to create practical ways to evaluate glass. Initially, TFs were derived only from a *tunnel test (described below).* More recently, data from field trials and other types of testing have been factored in.

Assigning Threat Factors Using Tunnel Testing

In 2003, Martin Rössler and Thomas Zuna-Kratky (2004) created the first "tunnel" at the Hohenau-Ringelsdorf Biological Station (Austria), to test proposed solutions to bird collisions on freestanding noise barriers. ABC's tunnels, using a second-generation design (Rössler et al., 2007), followed in 2009 and 2021. Tunnel testing is a non-injurious, standardized binomial choice technique that uses wild songbirds to determine the relative effectiveness of different patterns of visual markers at deterring bird collisions. In the U.S., tunnel testing takes place at American Bird Conservancy's tunnel at either the Carnegie Museum of Natural History's Powdermill Avian Research Center or at Washington College's Foreman's Branch Bird Observatory .

In a test flight, a bird flies down a completely dark space, the 'tunnel' (Figure 1), toward light at the far end, where side-by-side panels of glass appear to offer exit routes (Figure 2). One of these panes of glass is clear, unmarked glass (the control, invisible to the bird) and the other has the pattern of visual markers under evaluation (the test pane). A net ensures that the bird is safely stopped before it can hit the glass. After one trial, the bird is immediately released. When few birds fly to the patterned glass, we believe that they see and are avoiding the visual markers. For a detailed description of the Powdermill and Hohenau tunnels, see Sheppard (2019) and Rössler et al. (2007).



Figure 1. Test Tunnel at Foreman's Branch



Figure 2. View of glass samples

Specimen Performance Index (SPI) of a material is calculated by flying at least 80 individual birds down the tunnel and recording the percent that fly toward the test pane. For example, suppose 80 birds flew down the tunnel, with 20 flying toward the test pattern and 60 toward the control.

25% (20/80) of the birds flew toward the test pattern and it would have SPI of 25. If there is no additional information, for example, from a field trial, then the TF is equal to the SPI.

Important considerations

- SPIs and TFs *do not* warranty the actual percent reduction in collisions to be expected when a product is installed on a building. In fact, the same product may perform better or worse due to facade orientation in the same building, façade detail creating traps or channels, habitat reflected, whether the glass is free-standing and other variables. Threat Factors are an index, measuring the relative response to different patterns and different glass builds by songbirds flown in the tunnel. However, where monitoring data on tunnel-tested products are available, they confirm that products with lower threat factors yield fewer collisions. **ABC defines "bird-friendly" materials as having a threat factor ≤ 30, corresponding to a conservative estimated reduction of collisions of at least 50% under real world conditions.**

- The lower the Threat Factor, the more effective the tested material will be at reducing collisions. This has been confirmed when data is available. However, the relationship between TF score and effectiveness does not appear to be linear, so one cannot say that a pattern with TF=15 is twice as effective as a pattern with TF=30.

- Strong reflections can reduce pattern effectiveness by obscuring the visual markers during part or all of the day, if the pattern is on an inside surface of the glass. Reflections vary with insolation and with the angle of view, from the strongest reflections at acute angles to the weakest reflections when glass is viewed head on (Figure 3)

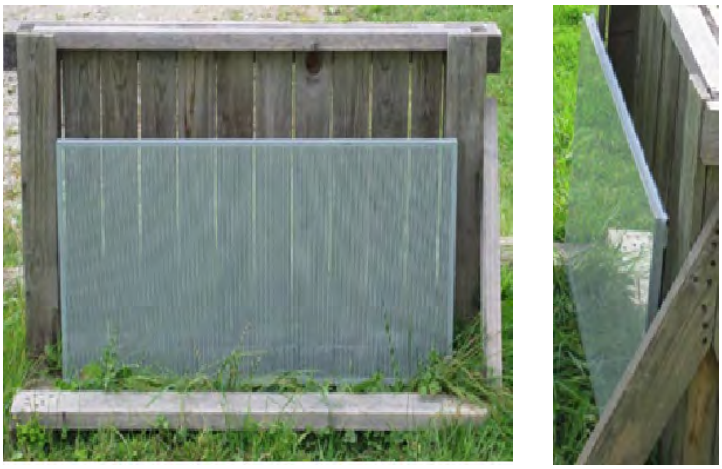


Figure 3: A single piece of glass with frit on surface 2, viewed head on (left) and from the side (right): The reflection is much stronger at an acute angle than it is head on. This glass has a surface reflectivity < 14%. However, for a bird to view this glass at an angle where there is a dangerous reflection, it would be flying almost parallel to the glass surface, where a collision would be unlikely to cause injury.

- ABC's tunnel test cannot replicate the range of possible reflections on a glass sample, so our tests model situations where a pattern is visible against a competing view. In the tunnel, birds see visual markers against a complex background (seen in figure 2), modeling situations where either the glass has only a moderate reflection or when birds can see through the glass to a landscape beyond. While it might seem at first that "reflection" and "see-through" conditions are quite different, in this context they are similar. In figure 4a, below, we cannot determine whether the image is a photo of a tree, a tree seen through a window, or the reflection of a tree. With the information in 4b, showing mullions, a crack, and right angles, we know glass is involved, but only with the information in figure 4c can we confirm that the image is a reflection and that we are not looking out the window at trees.



Figure 4a.



4b.



4c.

- ABC does not test materials with greater than 15% reflection (VLR) at the exterior surface of the glass, unless the visual markers are on the outside surface, or our BirdVis app (see appendix II) shows that there is sufficient contrast for markers to show through reflections.

- Because reflections on glass are both site and product specific, reflections should be considered early in the design process. Recommended design phase analysis ideally involves samples of glass viewed on the project site from a variety of angles, at different times of day, and with all potential site-specific reflections taken into consideration.

Spacing of Visual Markers

Where early recommendations, based on research by Klem (1990) and Rössler et al. (2007), showed that horizontal lines spaced 2" (5cm) apart and vertical lines spaced 4" (10cm) apart significantly reduced collisions, subsequent monitoring showed that the 4" spacing does not stop collisions by the smallest birds, especially hummingbirds. The spacing guideline for the Prescriptive Rating Option assigns a lower score when there is 2" (5 cm) spacing between the pattern's visual markers vertically and horizontally and a higher score for patterns with 4" (10 cm) horizontal spacing. Two inch (5 cm) spacing for two-dimensional patterns on glass or window film is now typically recommended in Canada (Canadian Standard A460) and increasingly in the United States. Thus, what was once the '2x4 rule' is now the '2x2 rule'. However, 2x4" spacing has been demonstrated to reduce collisions significantly and materials based on that guideline can still receive a 'bird-friendly' TF rating.

Visual Acuity

For a pattern of visual markers on glass or other materials to successfully deter bird collisions, birds must be able to perceive it in time to change course. The pattern of visual markers must be of an appropriate size and spacing and must be distinguishable from the both glass and any reflections or the view through the glass (e.g., habitat, sky, water, a potential flight path, etc.). We have adopted 9'-9' ½" (3 meters) as the standard viewing distance from which birds must be able to detect the pattern, following Ros et al. (2017).

Our instinct is to use human vision as a proxy for what birds can see. However, birds can see more colors and even perceive the earth's magnetic field, while humans have much better visual acuity. 'Visual acuity', the ability to resolve spatial features depends on the size of the eye and the number of photoreceptors in the retina. Songbird eyes are much smaller than human eyes. Because of this, birds, particularly small birds like songbirds, have very poor visual acuity in comparison to humans. Therefore, a pattern that appears quite visible to us may not be apparent at all to birds (Caves, Brandley and Johnsen, 2018).

Ultraviolet Patterns

Products with UV patterns should be considered carefully for some applications: Materials with ultra-violet patterns will vary in effectiveness with the amount of UV light present. This means that when the UV index is low – under low light conditions in early morning or evening or if the glass is shaded, or when it is overcast – UV patterns will be less visible to birds. In addition, not all types of birds can see UV. For example, songbirds can see UV, raptors and pigeons cannot.

Assigning Threat Factors Without a Tunnel Test

Not all materials need to be tunnel tested, specifically materials that are similar to others previously tested. ABC partners with the Bird-Safe Buildings Alliance (BSBA), a group of architects experienced in bird-friendly design, conservation biologists, and others with collisions expertise, to provide TFs for materials similar to those already rated. These ratings are very conservative: the rating assigned is the maximum expected TF; lower ratings might be obtainable through actual tunnel testing.

TFs can be assigned by review, instead of by tunnel test, to products that: a) were tested using other, peer-reviewed protocols that ABC and BSBA have determined to be equivalent or translatable to tunnel testing scores, b) were studied by scientists or experienced building collision monitors with a documented reduction in collisions of at least 50%, or c) comply with ABC's Prescriptive Rating Option (Appendix III). The Prescriptive Rating Option describes only a subset of materials that can be rated by other methods.

Appendix I. Definitions

Acid Etch: the use of hydrofluoric acid on glass to create translucent visual markers with texture and a 'frosted' appearance.

Exterior Visible Light Reflection (VLR): Net Exterior (measured at surface 1) reflection of complete glass build, including any coatings, (for the purpose of the prescriptive rating option, the VLR excludes visual markers)

Gloss reading of markers (60°): Please see ASTM D523 Standard Test Method for Specular Gloss

Opaque: Visible Light Transmission (VLT) = 0

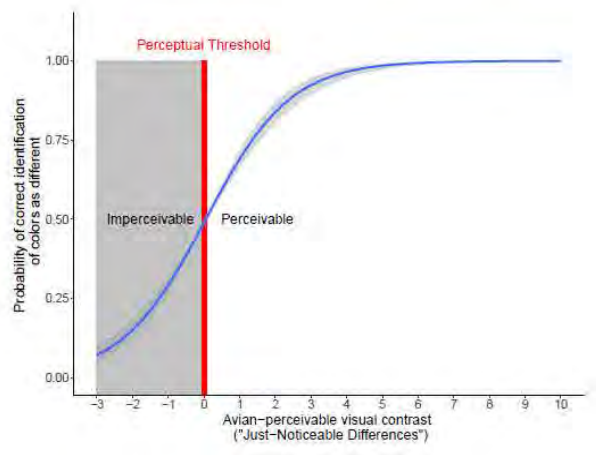
Pattern: Spatial arrangement and dimensions of visual markers on glass.

Visual Contrast: A difference in visual appearance of two surfaces sufficient for birds to distinguish between the two surfaces.

Appendix II. The BirdVis App: Avian Visual Contrast Levels

Because human perception is unreliable for evaluating what is sufficiently visible to birds, the Bird-safe Buildings Alliance contracted for the creation of an app, based on properties of the avian retina and studies of avian visual acuity. The BirdVis app (3.140.67.204:3838 Luro, 2021) calculates contrast level between the pattern of visual markers and glass (visual contrast level or VCL) and also displays pattern resolution.

Visual contrast is a difference in visual appearance sufficient to distinguish between two surfaces or two areas on the same surface. BirdVis uses the spectral reflectance of glass and associated pattern of visual markers, as well as data on avian eyes to model visibility of a pattern applied or integral to a particular glass. Visual Contrast Levels (VCL) are quantitative estimates of how visible (to birds) a pattern is against the associated glass.



BirdVis sets an avian 'just perceivable' visual contrast level at 0. This means a pattern/glass combination with a VCL value > 0 is determined to be sufficiently visible to birds (perceivable), while VCL values ≤ 0 indicate the pattern will likely not be seen against the glass by birds (unperceivable). Contrast values much greater than 0 (e.g., 5 and above) are predicted to be highly visible to birds.

The BirdVis model incorporates 4 main variables:

1) the avian visual system (bird photoreceptor sensitivities + simulated "neural noise" for each photoreceptor type),
2) the reflectance of glass and pattern samples,
3) the background against which the glass sample/pattern is viewed (this is ignored in the current model; it doesn't change the model estimates much because of visual adaptation to backgrounds), and
4) the types of light illuminating the glass and glass pattern (illuminants).

The model uses three illuminants: Midday sunlight (or Daylight, "D65, the international CIE-standard illuminant for average midday sunlight. cf Schanda, 2007), Blue Sky, and Forest Shade (Endler, 1993). The calculated avian visual contrast values are the mean of visual models across a handful of passerine species using all three illuminants (every bird visual system + illuminant combination is modeled). We can eventually change the illuminant using any light source as long as we can get absolute spectral irradiance measurements for it, meaning we could model how the glass appears at different locations and times of day.

Appendix III.
Assigning Threat Factors via Prescriptive Rating Option

All materials with assigned Threat Factors can be found here

Prescriptive Criteria for Glass with Opaque, non-metallic 2" x 2" Patterns

Bird-friendly glass assemblies that meet the following requirements are assigned a

Threat Factor of 20.

The glass assembly must have **all three** of the following characteristics:

I.

a. Surface one patterns only: No limit on VLR
    i. Acid etch
        1. Clear, low-iron, or tinted glass
        2. Gloss reading of etch markers (60°) ≤ 6

    or

    ii. Opaque frit or other opaque, non-metallic marker
        1. Clear or low-iron glass

OR

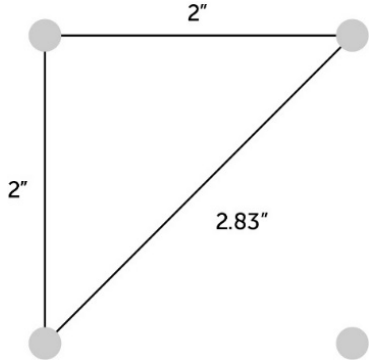
b. Surface two patterns only: VLR must be ≤ 15%
    i. Opaque frit or other opaque, non-metallic marker
        1. Clear or low-iron glass

II. As viewed from surface 1, all low emissivity (low-E) coatings must be behind pattern.

III. A pattern of visual markers comprising one of the following marker types or a combination:

b. Continuous solid lines at least 1/8" wide (~3mm), nowhere more than 2" apart, measured edge to edge.

c. Circular, square, or irregular solid shapes that are nowhere more than 2" from the nearest shape, measured horizontally or vertically, (edge to edge) and no more than 2.83" diagonally to the nearest shape (see diagram below). Each shape must have a minimum area of ≥ 0.049 in^2, which corresponds approximately with circles of diameter ¼" (~6mm).



Prescriptive Criteria for Glass with Opaque, 2” x 4” Patterns

Bird-friendly glass assemblies that meet the following requirements are assigned a

Threat Factor of 25.

The glass assembly must have **all three** of the following characteristics:

I.

a. Surface one patterns only: No limit on VLR
    i. Acid etch
        1. Clear, low-iron, or tinted glass
        2. Gloss reading of etch markers (60°) ≤ 6

    or

    ii. Opaque frit or other non-metallic, opaque marker
        1. Clear or low-iron glass

OR

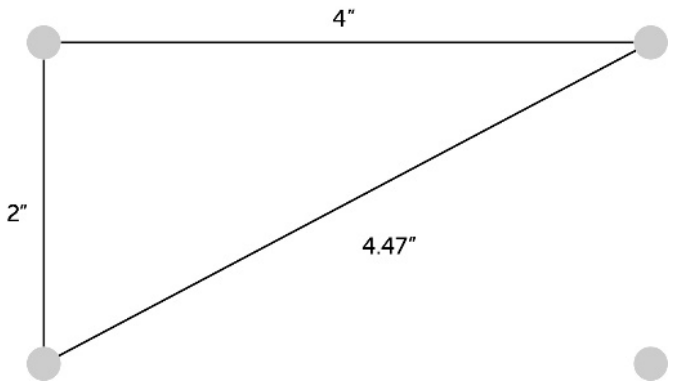
b. Surface two patterns only: VLR must be ≤ 15%
    i. Opaque frit or other non-metallic, opaque marker
        1. Clear or low-iron glass

II. As viewed from surface one, all low emissivity (low-E) coatings must be behind pattern.

III. A pattern of visual markers comprising one of the following marker types or a combination:

a. Continuous solid lines at least 1/8” wide (~3mm), nowhere more than 2” apart for horizontal or angled lines, 4” for vertical lines, measured edge to edge.

b. Circular, square, or irregular solid shapes that are nowhere more than 2” from the nearest shape vertically and nowhere more than 4” from the nearest shape horizontally, or 4.47” to the nearest shape diagonally, measured edge to edge (see diagram below). Each shape must have an area of ≥ 0.049 in^2, which corresponds approximately with circles of diameter ¼” (~6mm).



Prescriptive Criteria for Glass with Opaque < 2" Patterns

Bird-friendly glass assemblies that meet the following requirements are assigned a

Threat Factor of 25.

The glass assembly must have **all three** of the following characteristics:

I.

a. Surface one patterns only: No limit on VLR
    i. Acid etch
        1. Clear, low-iron, or tinted glass
        2. Gloss reading of etch markers (60°) ≤ 6

    or

    ii. Opaque frit or other opaque, non-metallic marker
        1. Clear or low-iron glass

OR

b. Surface two patterns only: VLR must be ≤ 15%
    i. Opaque frit or other opaque, non-metallic markers
        1. Clear or low-iron glass

II. As viewed from surface one, all low emissivity (low-E) coatings must be behind pattern.

III. A pattern of visual markers comprising one of the following elements or a combination:

a. Continuous solid lines at least ¼" wide and spacing equivalent to line width, measured edge to edge, up to < 2".
b. Circular, square, or irregular, solid shapes with spacing between shapes no less than diameter of pattern's visual markers and no more than 2", measured edge to edge. Each shape must have a minimum area of ≥ 0.049 in^2, which corresponds approximately with circles of diameter ¼" (~6mm).

Prescriptive Criteria for Façade Materials without Patterns

-including Spandrel Glass-

Glass builds and Façade Materials that meet the following requirements are assigned a

Threat Factor of 25

I. Surface one is continuous acid-etch with a gloss reading (60°) ≤ 16.

II. Surface is stainless steel, ASTM finish 2B or 4.

References

Cassey P, Honza M, Grim T, & Hauber ME. 2008. The modelling of avian visual perception predicts behavioural rejection responses to foreign egg colours. Biology Letters 4(5):515-7. https://doi.org/10.1098/rsbl.2008.0279

Caves EM, Brandley NC, Johnsen S. 2018. Visual acuity and the evolution of signals. Trends in Ecology & Evolution 33(5):358-72. https://doi.org/10.1016/j.tree.2018.03.00

Caves, Eleanor M. and Sönke Johnsen. 2017. AcuityView: An R package for portraying the effects of visual acuity on scenes observed by an animal. Methods in Ecology and Evolution 9(3):793-7. https://doi.org/10.1111/2041-210X.12911

Chadwick AC, Kentridge RW. 2015. The perception of gloss: A review. Vision research 109:221-35. https://doi.org/10.1016/j.visres.2014.10.026

Endler JA. The color of light in forests and its implications. 1993. Ecological monographs 63(1):1-27. https://doi.org/10.2307/2937121.

Luro, Alec B. 2021. BirdVis 1.0.0. Bird-Safe Buildings Alliance. http://3.140.67.204:3838/.

Luro AB, Fernández-Juricic E, Baumhardt P, Hauber ME. Visual acuity and egg spatial chromatic contrast predict egg rejection behavior of American robins. 2020. Journal of Experimental Biology 223(20):jeb229609. https://doi.org/10.1242/jeb.229609

Ros IG, Bhagavatula PS, Lin HT, Biewener AA. 2017. Rules to fly by: pigeons navigating horizontal obstacles limit steering by selecting gaps most aligned to their flight direction. Interface Focus 7(1):20160093. https://doi.org/10.1098/rsfs.2016.0093

Thomas RJ, Kelly DJ, Goodship NM. 2004. Eye design in birds and visual constraints on behavior. Ornitologia Neotropical 15(suppl):243-50.

Schanda, J. (Ed.). 2007. Colorimetry: understanding the CIE system. John Wiley & Sons. Hoboken, New Jersey, USA.

B2403.6-24 – Staff Summary

Proponent: William Penniman, representing Northern Virginia Bird Alliance; Thomas Blackburn, Northern Virginia, representing Northern Virginia Bird Alliance; and Sonal Shah, Northern Virginia, representing Northern Virginia Bird Alliance

Brief Description: Adds requirements for bird-friendly design and construction to the VCC.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting — 01/06/2026

Support: None

Opposition: Steve Shapiro, Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA); Dan Willham, Fairfax County and Virginia Building and Code Officials Association (VBCOA); Andrew Clark, Home Builders Association of Virginia (HBAV); Rick Hinson, American Council of Engineering Companies (ACEC); and Paul Messplay, Hanover County.

Discussion:

Tom Blackburn provided an overview of the proposal.

i. **Sonal Shah** advised that as availability and awareness increases for these products, the cost will be driven down.
ii. **Steve Shapiro** commented that these requirements are beyond the intent of the code to provide the minimum for health, safety, and welfare. The costs are also enormous. Also, it is not known if the reference standard being proposed has been reviewed to see if it meets the ICC requirements for reference standards.
iii. **Dan Willham** agreed with **Steve Shapiro** that this proposal is outside of the scope of the VCC.
iv. **Andrew Clark** alerted the group that the lead time to get some of these products is eight to ten months.

DHCD Staff Note:

The VRC companion proposal RB324.7-24 was also discussed at the same GSW meeting and received a Non-Consensus recommendation.

B3002.4-24

IBC: 3002.4

Proponents: Lyle Solla-Yates, representing Charlottesville Planning Commission (lyle.sollayates@gmail.com); Jared Calfee, representing AARP Virginia (jkcalfee@aarp.org)

2024 International Building Code

Revise as follows:

3002.4 Elevator car to accommodate ambulance stretcher. Where elevators are provided in *buildings* four or more *stories* above, or four or more *stories* below, *grade plane*, not fewer than one elevator shall be provided for fire department emergency access to all floors. The elevator car shall be of such a size and arrangement to accommodate an ambulance stretcher 24 inches by 84 inches (610 mm by 2134 mm) with not less than 5-inch (127 mm) radius corners, in the horizontal, open position and shall be identified by the international symbol for emergency medical services (star of life). The symbol shall be not less than 3 inches (76 mm) in height and shall be placed inside on both sides of the hoistway door frame.

Exception: Elevator cars are not required to accommodate ambulance stretchers in buildings complying with all of the following:

1. Group R-2 occupancies located above the level of exit discharge,
2. Not more than six stories in height above grade plane,
3. Each story above the level of exit discharge is not more than 4,000 net square feet (371.6 m2), and
4. Not a high-rise building.

Reason Statement: The purpose here is to maximize the odds that an elevator will be provided in small buildings by reducing size and cost. This issue is more pressing as taller single-stair buildings become more widely permitted in Virginia. These buildings have few units to share the high cost of an elevator, and experience in Seattle and New York City has shown that it is not economically viable to add stretcher-sized elevators to small buildings without subsidy.

The IBC currently contains a perverse incentive around elevators: there is no requirement in any part of the code to install an elevator in an R-2 building, but if one is voluntarily provided, requirements become increasingly stringent as buildings get taller, acting as a disincentive to install an elevator. This is a particular problem in the United States, as elevators cost around three times as much to install as they do in peer high-income countries, and can cost even more to maintain, even after adjusting for cost-of-living differences.

There are also higher opportunity costs of the floor area used, due to the larger cabins required.The result is that the United States has fewer elevators per capita than any other high-income country. The lack of elevators here in Virginia becomes an increasing problem due to our aging population and our increasingly high housing costs.

Rules requiring two staircases in multifamily buildings over three stories result in relatively large floor plates and high costs. As a result, new four-story walk-ups in the United States are rare, but they are likely to become more common. Reforms to Chapter 1006 considered for the 2027 IBC and approved by the Egress Committee in 2024 would make single-exit four-story buildings with small floor plates more common, making this need more urgent.

Evidence from New York City and Seattle, where locally adopted versions of Chapter 1006 have long allowed single-exit buildings of four to six stories, suggests that many of these buildings would be built as walk-ups. New York City is one of the few jurisdictions in America to contain a building code requirement to install an elevator starting at five stories, and according to Stephen Smith's research, developers there attempt to avoid it – for example by creating bilevel apartments on the top two stories to skirt the requirement, or filing for vertical alterations of older structures under an older code that does not contain an elevator requirement. None of the above is true in America's peer high-income countries. Elevators are a standard feature of small three-story buildings in Western Europe, and are often provided even when not required, because the costs are low enough and cabin sizes are small enough that the benefits outweigh the costs.

Code requirements come with costs and benefits that must be weighed against each other. A cabin that can accommodate a fully flat 84-in. stretcher has life safety benefits in certain emergency situations, but also costs. These costs come in dollars and square feet, but also in life safety and accessibility. If an elevator becomes too onerous to install, then there are much more severe life safety costs, both to occupants whose evacuation will be delayed by having to take the stairs, and to emergency responders who will have to carry them down the stairs. The building also becomes inaccessible to the 12 percent of the U.S. adult population that struggles with stairs.

Occupants of walk-ups are more likely to become one of the 1 million Americans treated in emergency rooms every year for stair-related injuries. There is no data on the number of Americans who die using stairs every year, but data from the UK extrapolated to our population suggests that it is in the thousands, exceeding the number of Americans who die in fires. There are countless situations where an elevator that can accommodate a wheelchair and a few people standing is useful, and many fewer situations where a patient must be evacuated in a fully flat stretcher.

Developers can avoid installing elevators of any size by building walk-up apartment buildings, but they can also – and often do – avoid building elevators by opting out of apartment buildings entirely and instead building townhouses, which never have elevators that can accommodate stretchers (and rarely have any elevator at all). In the economic analysis performed for the City of Charlottesville, it was found that townhouses were dramatically more economically attractive due to high cost barriers including high cost elevator mandates.

A recent apartment development in Albemarle County, Virginia gives a helpful example of how the private market is responding to the current size mandate. Fifth Street Place offers a number of amenities in their five residential buildings, including elevator service only in two of them.

Stephen Smith's analysis of buildings constructed in New York City since 2000 shows that the likelihood of installing an elevator in an apartment building exceeds 50 percent only when the building exceeds 24,000 sq. ft. of floor area. In other words, buildings below this size are at high risk of not having an elevator at all, and reasonable costs (both in dollars and square feet consumed) are especially important to ensuring that one is provided. This number forms the basis of this code proposal: 24,000 sq. ft. of total floor area in a six-story building equates to roughly 20,000 sq. ft. above the ground floor. This assumed floor plate also aligns with limits found in other high-income countries.

Beyond the accessibility benefits of elevators themselves, the installation of an elevator in a building that would otherwise be a walk-up or a series of townhouses also triggers further accessibility within units themselves, given how the Fair Housing Amendments Act guidelines treat elevatored buildings as compared to walk-ups.

This proposed exception applies only to multifamily buildings up to six stories. It also excludes high-rise buildings, to avoid applying to buildings with very tall ceilings or mezzanines. Virginia lawmakers are growing concerned about the large cost premium for elevators in Virginia, and legislators in Washington State have introduced bills to remove the stretcher requirement for multifamily buildings of roughly the size covered by this exception, supported by the state AARP chapter.

Bibliography: The support for the reason statement comes from Stephen Smith's 122-page comparative report on elevators in North America and high-income peer countries, found here: https://bit.ly/3XRH4Ij

The issues discussed in the reason statement are addressed on the following pages:

- 15: Per-capita elevator stock by country
- 16-18: Rarity of new walk-up apartment buildings in Western Europe
- 19-23: Ubiquity of new walk-up buildings in the United States
- 35-36: Installation costs for elevators in new buildings in the U.S. vs. Western Europe
- 42: Life safety considerations in buildings without elevators
- 43-55: In-depth discussion of cabin sizes (history, U.S. and foreign practices, cost implications)

Bills introduced in Washington State and Connecticut

- 1183.pdf
- 5156.pdf
- C G A - Connecticut General Assembly

Cost Impact: The code change proposal will decrease the cost

Estimated Immediate Cost Impact:

Substantial in instances where developers opt for a smaller elevator (at least $10,000)

Estimated Immediate Cost Impact Justification (methodology and variables):

Interviews with those in the elevator industry and review of dozens of proposals for installation. Thanks to Stephen Smith for that work.

Estimated Life Cycle Cost Impact:

Decrease, with an uncertain magnitude (larger equipment costs more to maintain).

B3002.4-24 – Staff Summary

Proponent: Lyle Solla-Yates, representing Charlottesville Planning Commission; Jared Calfee, representing AARP Virginia

Brief Description: Exempts elevator cars in qualifying R-2 buildings six stories or less above grade plane from the requirement to accommodate ambulance stretchers.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Second GSW Meeting — 10/03/2025

Support: Andrew Clark, Home Builders Association of Virginia (HBAV); William Abrahamson, American Institute of Architects, VA Chapter (AIA-VA); and Rory Stolzenberg, Charlottesville Planning Commission.

Opposition: Andrew Milliken, Stafford County Fire Marshal's Office and Virginia Fire Services Board (VFSB) Codes and Standards Committee; and Lee Stoermer, representing himself.

Discussion:

Lyle Solla-Yates provided an overview of the proposal and the associated floor modification, explaining that the language from the original proposal is being changed with the floor modification from "with the following" to "with all of the following" for clarity and to ensure all listed requirements must be met.

a. **Andrew C** expressed support for the proposal but suggested that the proponent should meet with other stakeholders to address any outstanding concerns and possibly improve the proposal further.
b. **William A** indicated support for the proposal.
c. **Rory S** explained that the proposal targets buildings that typically do not have elevators due to their high cost. He argued that adopting this proposal could encourage the installation of additional elevators, which would improve both evacuation during emergencies and firefighter access.
d. **Andrew M** strongly opposed the intent of the proposal.
e. **Lee S** (speaking on behalf of himself) opposed the proposal, describing the practical difficulties of evacuating patients on backboards down multiple flights of stairs, a process that requires 5-6 people. Lee argued that elevators would allow just 2 people to transport someone, highlighting the safety and efficiency benefits of elevator access in emergencies.

DHCD Staff Note: N/A

B3104.1.1-24

IBC: 3104.1.1, Chapter 35: (New)

Proponents: Mekonnen Gebresillasie, Fairfax county, VA, representing Land development services (mekonnen.gebresillasie@fairfaxcounty.gov)

2024 International Building Code

Revise as follows:

3104.1.1 Application. *Pedestrian walkways* shall be designed and constructed in accordance with Sections 3104.2 through ~~3104.9.~~ 3104.9 or per AASHTO LRFD Bridge Design Specifications. Tunnels shall be designed and constructed in accordance with Sections 3104.2 and 3104.10.

Chapter 35: Referenced Standards. Add new promulgator and standard, as follows:

AASHTO	American Association of State Highway and Transportation 555 12Th Street NW, Suite 1000 Washington, DC 20004	

AASHTO LRFD Bridge Design Specifications, 10th Edition

Reason Statement: Most retaining walls, pedestrian bridges, and wingwalls associated with these structures are designed using the AASHTO standard as a reference. However, because AASHTO is not listed in Chapter 35 of the Virginia Construction Code (VCC), many jurisdictions require a formal code modification to demonstrate equivalency with the VCC.

Incorporating the AASHTO standard into the referenced codes section of the VCC would streamline the permitting process. Designers could proceed without needing a separate code modification, resulting in faster approvals and reduced costs for both jurisdictions and applicants.

Cost Impact: The code change proposal will decrease the cost The current process for obtaining code modifications is time-consuming and project-specific. Each time a customer submits a design based on AASHTO standards, a separate code modification must be approved. This not only delays permitting but also incurs additional fees for the applicant.

B3104.1.1-24 – Staff Summary

Proponent: Mekonnen Gebresillasie, Fairfax County, VA, representing Land development services

Brief Description: Allows the use of American Association of State Highway and Transportation (AASHTO) Bridge Design Specifications as an alternative method of design and construction for pedestrian walkways.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting — 01/06/2026

Support: None

Opposition: Dan Willham**,** Fairfax County and Virginia Building and Code Officials Association (VBCOA); and Doug Banks, Henrico County.

Discussion:

Dan W commented that AASHTO is a structural standard that does not have any safety criteria related to pedestrian bridges, and that this is the wrong section of the code to try to bring in AASHTO.

DHCD Staff Note: N/A

B3105.2-24

IBC: 3105.2

Proponents: Mekonnen Gebresillasie, Fairfax county, VA, representing Land development services (mekonnen.gebresillasie@fairfaxcounty.gov)

2024 International Building Code

Revise as follows:

3105.2 Design and construction. *Awnings* and *canopies* shall be designed and constructed to withstand wind or other lateral *loads* and *live loads* as required by Chapter 16 with due allowance for shape, open construction and similar features that relieve the pressures or loads. Structural members shall be protected to prevent deterioration. *Awnings and canopies* shall have frames of noncombustible material, *fire-retardant-treated wood*, heavy timber complying with Section 2304.11 or 1-hour construction, and shall be fixed, retractable, folding or collapsible.

Reason Statement: This section is about awnings and canopies. The intent of the proposed code change is to establish a minimum construction type requirement for canopies, aligning it with that already specified for awnings

Cost Impact: The code change proposal will not increase or decrease the cost There is no cost impact. Some Jurisdictions are using the construction type of canopies similar to awnings. This is just to create consitency.

Public Comments (PCH) for: B3105.2-24

Discussion by Mekonnen Gebresillasie

Oct 7, 2025 18:23 UTC

3105.2 clarifying constriction type of Canopies. 3105.2Design and construction. Awnings and canopies shall be designed and constructed to withstand wind or other lateral loads and live loads as required by Chapter 16with due allowance for shape, open construction and similar features that relieve the pressures or loads. Structural members shall be protected to prevent deterioration. Awnings and canopies shall have frames of noncombustible material, fire-retardant-treated wood, heavy timber complying with Section 2304.11, or 1- hour construction with combustible or noncombustible covers and shall be either fixed, retractable, folding or collapsible.

Proposal # 1467

B3105.2-24 – Staff Summary

Proponent: Mekonnen Gebresillasie, Fairfax County, VA, representing Land Development Services

Brief Description: Requires “canopies” to have frames of non-combustible material, fire-retardant-treated wood, heavy timber, or 1-hour construction, similar to awnings.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting — 01/06/2026

Support: None

Opposition: Dan Willham, Virginia Building and Code Officials Association (VBCOA).

Discussion:

Dan W, representing VBCOA, explained that canopies are different from awnings. Awnings are part of the building façade, hence the non-combustible frame requirement. Canopies are not required to be connected to a building at all, so there is no reason for canopies to be held to the same frame requirements of awnings.

DHCD Staff Note: N/A

B3500-24

IBC: CHAPTER 35, 35 ASCE/SEI, ASCE/SEI Chapter 35

Proponents: Mark Dreyer, Commonwealth of Virginia - Department of General Services, representing Division of Engineering and Buildings (mark.dreyer@dgs.virginia.gov)

2024 International Building Code

CHAPTER 35
REFERENCED STANDARDS

ASCE/SEI

American Society of Civil Engineers Structural Engineering Institute
1801 Alexander Bell Drive
Reston, VA 20191

Revise as follows:

7—22 (Including Supplements 1 and 2)	Minimum Design Loads and Associated Criteria for Buildings and Other Structures
~~24—14~~ 24—24	Flood Resistant Design and Construction

Reason Statement: Adopting these code updates in the Virginia Construction Code (VCC) would ensure that Virginia remains in step with the latest code developments toward achieving flood resiliency. It will support the Virginia Flood Protection Master Plan initiative with up-to-date engineering criteria that ensure the safety and durability of structures in Virginia's floodplains.

The ASCE 24-24 (Flood Resistant Design and Construction) is a major update to the ASCE 24-14 and represents a significant upgrade in the nation's flood loss reduction standards. It is based on the ASCE 7-22 (Minimum Design Loads and Associated Criteria for Buildings and Other Structures), Supplement 2 (88 pages), which was issued in May 2023. In ASCE/SEI 7-22 Supplement 2, the Flood Hazard Area is increased from the 100-year flood plain to the 500-year flood plain for Risk Categories II, III, and IV structures to improve the performance of structures subjected to flood events and to meet the target reliabilities of the standard. This change in approach, along with revised loading equations, is a significant departure from previous versions of ASCE 7. In addition to other updates in this supplement, the majority of Chapter 5, Flood Loads, and its commentary have been updated. Elevation requirements in the ASCE 24-24 now include consideration of sea level rise. An online pilot tool called the ASCE 24-24 Minimum Required Elevation Calculator has also been developed by the LSU Ag Center, which may eventually be incorporated into the ASCE Hazard Tool.

The updated standards are developed by the ASCE, a premier professional organization which is at the forefront of establishing standards for civil engineering design and practice worldwide, each standard representing a broad consensus of the related professional community. These standards are aimed at reducing flood losses, reported at ~ 45 billion annually nationwide (https://www.floods.org/news-views/flood-mitigation/asce-24-24-delivers-major-update-to-flood-resistant-design-standards/). In Virginia's coastal areas alone (Virginia Coastal Resilience Master Plan website - https://www.dcr.virginia.gov/crmp/plan), between 2020 and 2080, the number of residential, public, and commercial buildings exposed to an extreme coastal flood is projected to increase by almost 150% from 140,000 to 340,000, while annualized flood damages increase by 1,300% from $0.4 to $5.1 billion.

With the increasing frequency of severe storms observed over the past decade, the updated design standards will protect against 500-year flood events, which is a significant improvement to the 100-year flood hazard referenced in the previous versions.

Cost Impact: The code change proposal will increase the cost

The updated standards are aimed at making buildings and structures more resilient to floods and reducing overall flood losses. However, due to consideration of the 500-year floodplain and factoring in sea level rise in the elevation requirements, as well as additional design requirements, the construction of buildings in the 100- year floodplain would be impacted by a marginal increase in cost. Additionally, new buildings and substantial improvement projects in the 500-year floodplain would also now be required to comply with the flood resistant design and construction standards. (According to a flood impact study conducted as part of the VFPMP process, the number of buildings exposed to flooding in 2020, was 260,351 buildings in the 100-year floodplain and 427960 buildings in the 500-year floodplain, with the numbers projected to increase to 314,835 and 491,193 respectively by 2060.)

In the ASCE 24-24, Flood Design Class 3 elevation is increased to Base Flood Elevation (BFE) + 2 feet or Design Flood Elevation (DFE) whichever is higher, instead of BFE +1 feet in the 2014 code version. The new ASCE 7-22 S-2 provisions require Risk Category II, III, and IV structures in the 500-year floodplain to use floods with the Mean Recurrence Interval (MRI) of 500, 750, and 1000 years respectively to determine flood loads. Risk Category II structures, the most commonly used category, include one- and two-family buildings, low to medium occupancy businesses, or recreational facilities. Risk Category I structures, including agricultural buildings such as barns and sheds, could still follow 100-year flood provisions. The supplement also introduces a new requirement for relative sea level change as it relates to each individual structure. The sea level rise estimated over the service life of the structure must be added to the design's flood mitigation plans. (https://www.structuremag.org/article/major-changes-to-asce-7-22-flood-loads/)

Foundations walls, footings, columns, piles, connections are to be designed for sustained flood loads and erosion/scour using the newly specified flood design loads and load combinations. Existing slabs on the ground are not permitted to be elevated unless evaluated and strengthened.

From the perspective of ASCE codes, the average cost of constructing a building in the floodplain compared to buildings that are not in the floodplain can be higher by 10% to 30% depending on: elevation, structural design for flood loads, materials and design for floodproofing, with approximately 5% to 10% incremental cost attributable to the updated standards for buildings in the 100-year floodplain. At the lower range of these costs would be Risk Category I and II buildings with relatively lower elevation and structural design criteria, with Risk Category III and IV buildings occupying the higher end of the cost spectrum.

Attached Files

- **asce-24-24-guidance-structural-safety-flood-introduction.pdf**
  https://va.cdpaccess.com/proposal/1349/1963/files/download/939/
- **asce 7-22.sup2.pdf**
  https://va.cdpaccess.com/proposal/1349/1963/files/download/938/
- **2024 code cycle ASCE.docx**
  https://va.cdpaccess.com/proposal/1349/1963/files/download/929/

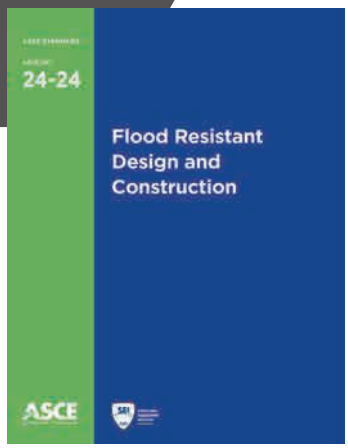


Guidance on Structural Safety in Flood Areas: ASCE 24-24

One of the most reliable ways to ensure increased performance and resilience of our nation's built environment is the widespread adoption and enforcement of up-to-date, modern building codes and standards.

Flood Resistant Design and Construction, ASCE/SEI 24-24

ASCE 24 provides minimum requirements for flood resistant design and construction of structures that are subject to building code requirements or floodplain management regulations in flood hazard areas and is intended to meet or exceed the requirements of the National Flood Insurance Program (NFIP). This standard applies to new construction, including subsequent work to such structures, and work classified as substantial improvement of existing structures that are not historic structures.



Key elements of the 2024 edition of ASCE 24:

- Alignment with the Supplement 2 of Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7-22)
- Updated for consistency with FEMA Technical Bulletins
- Updates to elevations, materials, and floodproofing

What is new in ASCE 24-24?

- In alignment with ASCE/SEI 7-22 Supplement 2:
  - The Flood Hazard Area is expanded to include land in the 500-year floodplain, and
  - The Design Flood Elevation corresponds to the greater of the elevation set by the community or the elevation pertaining to the MRI flood event for the Flood Design Class plus Sea Level Rise;

ASCE is an ANSI-accredited standards development organization (SDO)

ASCE Standards provide technical requirements or guidelines for promoting safety, reliability, productivity, and efficiency in civil engineering.

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- Clarifications to Flood Design Class for agricultural structures, hospitals, health care facilities, and ambulatory care facilities;
- Definitions for residential portions of mixed-use buildings and flood barriers and shields;
- Use of flood mitigation pumps and valves for passage of water and removal of accumulated water;
- Inspection and maintenance needs and flood emergency operation plans; and
- Placement of attendant utilities and equipment; and automatic pressure control valves for gas and fuel supply lines.

How does ASCE 24-24 help communities?

ASCE 24 provides guidance to design and construction in flood prone areas. The disasters resulting from Hurricane Helene (Sept 2024) and Hurricane Harvey (Aug 2017) are examples of the devastation caused by flooding. Major flooding events can lead to large-scale damage to homes, disruption of life-sustaining services, and transportation and supply chain delays. Community officials, floodplain managers, and design professionals can apply this standard to protect public safety and property.

Who is using it?

ASCE 24-24 is a primary reference for structural engineers and registered design professionals to evaluate measures that may reduce vulnerability to future floods. It covers the basic flood requirements, as well as high-risk and coastal hazard areas. Using this standard, engineers can focus on key structural areas, including foundation design, materials to use in flood zones, floodproofing, and electrical and plumbing systems. Structural engineers, design professionals, code officials, floodplain managers, and building owners will find this guidance on design and construction in flood prone areas essential. The standard is adopted by reference in model building codes.



ASCE 24-24 IS AVAILABLE IN:

- Print
- E-book PDF
- Interactive digital access on the AMPLIFY platform, ***amplify.asce.org***

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Standard 7-22
Minimum Design Loads and Associated Criteria for Buildings and Other Structures

SUPPLEMENT 2

Chapter 1: General

1.3.1.3 Performance Based Procedures

Structural and nonstructural components and their connections designed with performance-based procedures shall be demonstrated by analysis in accordance with Section 2.3.5 or by analysis procedures supplemented by testing to provide a reliability that is generally consistent with the target reliabilities stipulated in this section.

Structural and nonstructural components subjected to dead, live, environmental, and other loads except earthquake, tsunami, and loads from extraordinary events shall be based on the target reliabilities in Table 1.3-1. Structural systems subjected to earthquake shall be based on the target reliabilities in Table 1.3-2 and 1.3-3. The design of structures subjected to tsunami loads shall be based on the target reliabilities in Table 1.3-4. Structures, components, and systems that are designed for extraordinary events, using the requirements of Section 2.5 for scenarios approved by the Authority Having Jurisdiction, shall be based on the target reliabilities in Table 1.3-5. The analysis procedures used shall account for uncertainties in loading and resistance.

Chapter 2: Combinations of Loads

2.2 SYMBOLS

A_k = Load or load effect arising from extraordinary event A

D = Dead load

D_i = Weight of ice

E = Earthquake load

F = Load caused by fluids with well-defined pressures and maximum heights

F_a = Flood load as defined by Section 5.5

H = Load due to lateral earth pressure (including lateral earth pressure from fixed or moving surcharge loads), ground water pressure, or pressure of bulk materials

L = Live load

L_r = Roof live load

N = Notional load for structural integrity, Section 1.4

R = Rain load

S = Snow load

T = Cumulative effect of self-straining forces and effects arising from contraction or expansion resulting from environmental or operational temperature changes, shrinkage, moisture changes, creep in component materials, movement caused by differential settlement, or combinations thereof

W = Wind load

W_i = Wind-on-ice determined in accordance with Chapter 10

2.3.2 Load Combinations Including Flood Load.
When a structure is located in a flood hazard area (Section 5.3.1), the following load combinations shall be considered in addition to the basic combinations in Section 2.3.1:

4b. $1.2D + 1.0W + 1.0F_a + 1.0L + (0.5L_r \text{ or } 0.3S \text{ or } 0.5R)$

5b. $0.9D + 0.5W + 1.0F_a$

Exception:

1. The load factor on L in the combination 4b is permitted to equal 0.5 for all occupancies in which L_o in Chapter 4, Table 4.3-1 is less than or equal to 100 psf (4.78 kN/m^2), with the exception of garages or areas occupied as places of public assembly.
2. In the load combination 4b, the companion load S shall be taken as either the flat roof snow load (p_f) or the sloped roof snow load (p_s).

2.4.2 Load Combinations Including Flood Load.

When a structure is located in a flood hazard area, the following load combinations shall be considered in addition to the basic combinations in Section 2.4.1:

5b. $D + 0.6W + 0.7F_a$

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6b. $D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } 0.7S \text{ or } R) + 0.7F_a$

7b. $0.6D + 0.6W + 0.7F_a$

EXCEPTION:

In the load combination 6b, the companion load S shall be taken as either the flat roof snow load (p_f) or the sloped roof snow load (p_s).

Chapter 5: Flood Loads

5.1 GENERAL

The provisions of this chapter apply to buildings and other structures located in a Flood Hazard Area.

This chapter shall not apply to the design of levees, dikes, piers, wharves, roads, or bridges.

5.2 DEFINITIONS AND SYMBOLS

5.2.1 Definitions

APPROVED: Acceptable to the Authority Having Jurisdiction.

BASE FLOOD: Flood having a 1 percent chance of being equaled or exceeded in any given year (100-year flood).

BASE FLOOD ELEVATION (BFE): Elevation of flooding, including wave height, having a 1 percent chance of being equaled or exceeded in any given year.

BREAKAWAY WALL: Any type of wall subject to flooding that is not required to provide structural support to a building or other structure and that is designed and constructed such that it will collapse under specific lateral loads, defined in Section 5.3.10, and it allows for the free passage of floodwaters without damaging the supporting structure or foundation system.

DEBRIS IMPACT FORCE: Force imparted by a flood-borne debris strike.

DESIGN FLOOD:

The flood corresponding to the design mean recurrence interval assigned by risk category in accordance with Table 5.3-1, including relative sea level change.

DESIGN STILLWATER FLOOD DEPTH: The stillwater depth, above the eroded grade at an individual building or other structure, produced by the design flood.

DESIGN STILLWATER FLOOD ELEVATION: The elevation, relative to the adopted datum, of the stillwater during the design flood, including relative sea level change. See Figures 5.2-1 and 5.2-2.

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ELEVATED STRUCTURE: A structure with its lowest habitable floor positioned above ground, raised on foundation walls, shear walls, posts, piers, pilings or columns, such that water may flow below the lowest habitable floor during a flooding condition.

EROSION: Wearing away of the land surface by detachment and movement of soil and rocks during a flood or storm or over a period of years, through the action of wind, water, or other geologic processes that result in a lowering of the ground surface.

FLOOD HAZARD AREA: The area subject to flooding as specified in Section 5.3.1.

FLOOD HAZARD MAP: The map delineating flood hazard areas adopted by the Authority Having Jurisdiction.

FLOOD HAZARD STUDY: Study that serves as the technical basis for a flood hazard map. A compilation and presentation of flood risk data for specific watercourses, lakes, and coastal flood hazard areas within a community.

FLOOD INSURANCE RATE MAP (FIRM): An official map of a community on which the Federal Emergency Management Agency (FEMA) has delineated both special flood hazard areas and the risk premium zones applicable to the community.

FLOOD ZONES:

A-Zone: Area subject to inundation by the 1 percent annual chance flood, (100-year flood), where wave action does not occur or where waves are less than 3 ft (0.9 m) high, designated Zone A, AE, A1- A30, A0, AH, or AR on a FIRM.

Coastal A-Zone: An area within a special flood hazard area, landward of a V-Zone or landward of an open coast without mapped Coastal High Hazard Areas. In a Coastal A-Zone, the principal source of flooding is astronomical tides and storm surges, but not riverine flooding, and the potential exists for breaking wave heights greater than or equal to 1.5 ft (0.46 m) during the base flood. The inland limit of the Coastal A-Zone is (1) the Limit of Moderate Wave Action if delineated on a FIRM, or (2) designated by the Authority Having Jurisdiction.

Coastal High Hazard Area (V-Zone): An area within a Special Flood Hazard Area, extending from offshore to the inland limit of a primary frontal dune along an open coast, and any other area that is subject to high velocity wave action from storms during the base flood. This area is designated on flood insurance rate maps (FIRMs) as V, VE, VO, or V1-30.

Shaded X-Zone: An area landward of the Special Flood Hazard Area, delineating the 0.2 percent annual chance of being equaled or exceeded in any given year flood (i.e., subject to inundation by the 500-year flood). This area is designated on FIRMs as X with a shading.

X-Zone: Areas outside the Special Flood Hazard Area. Unshaded Zone X designated areas are where the annual probability of flooding is less than 0.2 percent.

HYDRODYNAMIC LOAD: Load imposed by water flowing against and around an object or structural element.

HYDROSTATIC LOAD: Load imposed by a standing mass of water, including buoyancy.

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LIMIT OF MODERATE WAVE ACTION (LiMWA): Line shown on FIRMs to indicate the inland limit of the 1.5 ft (0.46m) breaking wave height during the 1 percent annual chance flood (100-year flood).

MEAN RECURRENCE INTERVAL (MRI): The reciprocal of the annual probability of exceedance. The average time, in years, between hazard events that equal or exceed a given magnitude, based on probability and statistical analysis.

MEAN WATER LEVEL (MWL): Mean water level relative to a locally adopted datum specified on a flood hazard map in the absence of flooding.

SCOUR: The local removal of soil or sediments around an object or structural element due to an abrupt change in flow direction or velocity from the design flood.

SITE-SPECIFIC STUDY: An alternative study using analytical, numerical, or experimental methods, approved by the Authority Having Jurisdiction, to determine flood depth, associated conditions, or flood loads, for a specific location.

SPECIAL FLOOD HAZARD AREA (AREA OF SPECIAL FLOOD HAZARD): The land in the floodplain subject to a 1 percent or greater chance of flooding in any given year. These areas are delineated on a community's FIRM as A-Zones (A, AE, A1-30, A99, AR, AO, or AH) or V-Zones (V, VE, VO, or V1-30).

STILLWATER ELEVATION (SWEL): Elevation of the surface of the water in the absence of waves that is referenced to a datum, excluding relative sea level change.

WAVE HEIGHT: Vertical distance between the crest and the trough of a wave.

Controlling Wave Height: The wave height associated with the mean of the highest 2 percent of waves associated with the design flood used to determine design wave height when the waves are not depth-limited.

Design Wave Height: The wave height at an individual building or other structure associated with the design flood, used to determine scour and wave loads.

Significant Wave Height: The wave height associated with the mean of the highest one-third of waves associated with the design flood, used to determine Controlling Wave Height when not known.

WAVE LOAD: Load imparted by a wave interacting with the structure or a portion thereof.

Breaking Wave Load: Load imparted by a breaking wave, often in depth-limited conditions.

Nonbreaking Wave Load: Load imparted by waves that are not breaking, which often occurs when the wave height is less than the height associated with depth-limited conditions.

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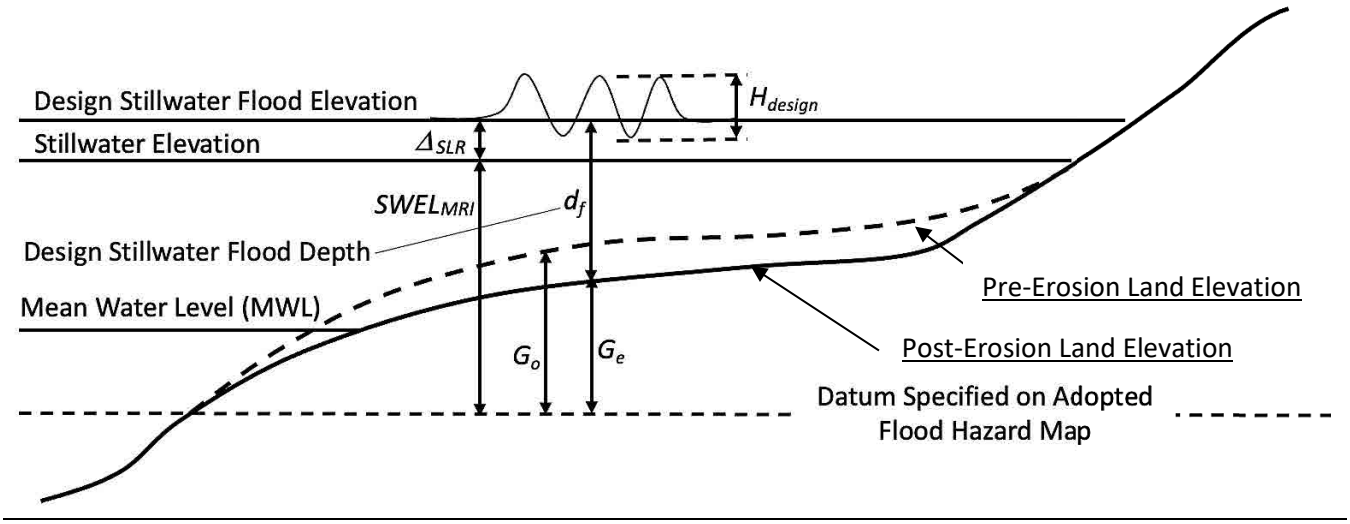


Figure 5.2-1. Flood Parameters in Coastal Areas.

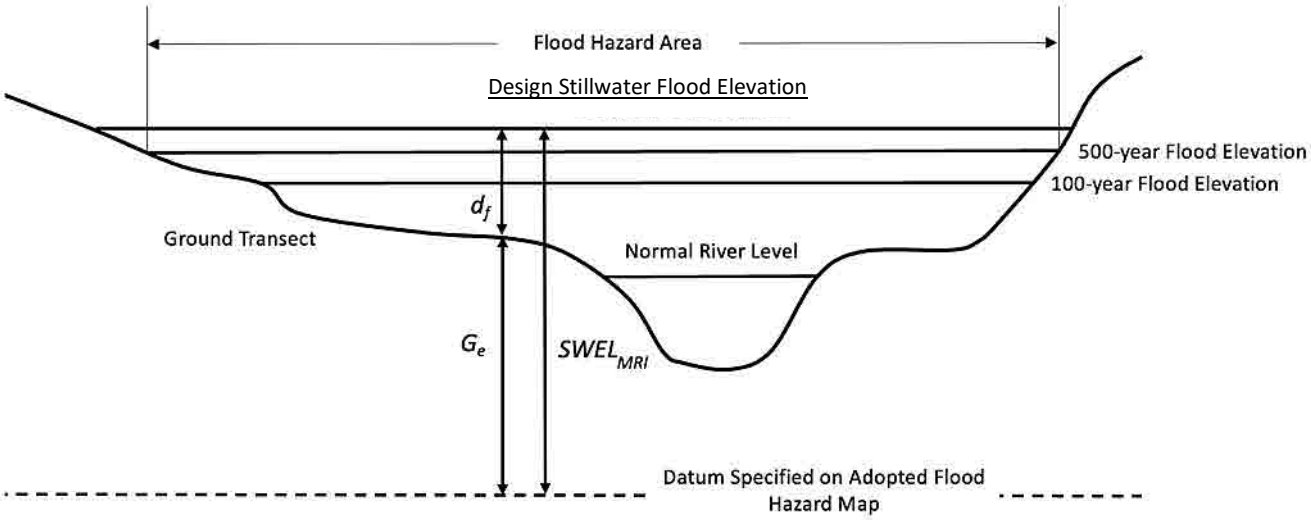


Figure 5.2-2. Flood Parameters in Riverine Areas.

5.2.2 Symbols and Notation

a = Air gap between lowest supporting horizontal structural member of lowest above grade floor and the design stillwater flood elevation, in ft (m)

A = Projected area in the flow direction exposed to moving water, including debris damming, in ft^2 (m^2)

b = Column width or width of a vertical wall, perpendicular to the direction of flow considered, in ft (m)

B = Overall width of building perpendicular to the flow direction, in ft (m)

C_{bw} = Coefficient for breaking waves

C_{br} Wave height coefficient for depth-limited breaking

C_{cx} = Debris damming closure ratio

C_D = Wave drag coefficient

C_d = Drag coefficient for submerged objects subjected to currents

C_{HC} = Scaling factor for controlling wave height

C_M = Inertia coefficient

C_{MRI} = Flood scale factor for mean recurrence interval

C_o = Debris orientation coefficient

C_R = Debris depth coefficient

C_s = Debris velocity stagnation coefficient

C_T = Wave period coefficient

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C_V = Velocity coefficient

C_{Vmax} = Coefficient of maximum velocity

D = Pile or column diameter, in ft (m)

D_{SW} = Self-weight of the structure or portion of structure being evaluated inclusive of permanent fixed elements and equipment, in lb (kN)

d_f = Design stillwater flood depth, in ft (m)

E = Modulus of elasticity, in psi (kPa)

F_a = Flood load used in the Chapter 2 load combinations, in lb (kN)

F_B = Uplift force caused by buoyancy, in lb (kN)

F_{bw} = Maximum net lateral force resulting from breaking waves on a vertical pile or column, in lb (kN)

F_{di} = Debris impact force, in lb (kN)

F_{drag} = Hydrodynamic drag force, exerted by moving water on structural components immersed in the flow and buildings immersed in the flow, in lb (kN)

F_{BNV} = Horizontal component of breaking wave force per unit length on a non-vertical wall, in lb/ft (kN/m)

F_{BOI} = Horizontal component of obliquely incident breaking wave force, in lb/ft (kN/m)

F_{BRK} = Breaking wave force per unit length on a vertical wall, in lb/ft (kN/m)

F_h = Lateral force caused by the hydrostatic pressure on one side of a vertical wall per unit width, in lb/ft (kN/m)

$F_{lateral}$ = Maximum lateral component of the flood load, F_a, in lb (kN)

F_t = Lateral wave-induced force per unit length on the vertical wall or structure, in lb/ft (kN/m)

F_m = Maximum net lateral force resulting from a nonbreaking wave, in lb (kN)

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g = Acceleration due to gravity, in ft/s^2 (m/s^2)

G_e = Elevation of grade at the building or other structure inclusive of effects of erosion in ft (m)

G_o = Original grade at the building or other structure in ft (m)

H = Wave height from crest to trough, in ft (m)

H_a = Resultant force from active lateral earth pressures, in lb (kN)

H_b = Breaking wave height, in ft (m)

H_c = Controlling wave height, in ft (m)

H_{c100} = Controlling wave height for the 100-year MRI, in ft (m)

H_{cMRI} = Controlling wave height corresponding to the risk category and MRI, in ft (m)

H_{design} = Design wave height, in ft (m)

H_p = Resultant force from passive lateral earth pressures, in lb (kN)

H_s = Significant wave height, in ft (m)

h = Submerged height of column or wall above its foundation or structural floor level, in ft (m)

h_c = Height in ft (m) to the top of the vertical wall or structure above the design stillwater flood elevation

k_e = Effective stiffness of the impacting debris or the effective lateral stiffness of the impacted structural element(s) deformed by the impact, in lb/ft (kN/m).

L = Wavelength, in ft (m)

m_{debris} = Mass of the debris (W_{debris}/g), in lb s^2/ft (kg).

p_h = Hydrostatic pressure at a given depth z, in lb/ft^2 (kN/m^2)

p_1 = Pressure at the design stillwater flood elevation, in lb/ft^2 (kN/m^2)

p_2 = Pressure at the top of the vertical wall or structure, in lb/ft^2 (kN/m^2)

p_3 = Pressure at the eroded ground elevation, in lb/ft^2 (kN/m^2)

p_4 = Pressure at the base of the structure, in lb/ft^2 (kN/m^2)

p_{1B} = Breaking wave pressure acting at the design stillwater flood elevation, in lb/ft^2 (kN/m^2)

R = Vertical wave runup distance from the design stillwater flood elevation, in ft (m)

R_B = Allowable uplift resisting capacity of structural foundation elements and/or other conditions resisting uplift, in lb (kN)

R_p = Allowable lateral resisting capacity of deep foundations, external structural foundation elements and/or other conditions resisting sliding, in lb (kN)

s = Average clear spacing of column or wall to the adjacent column or wall in ft (m)

S_m = Maximum scour depth, in ft (m)

$SWEL_{MRI}$ = Stillwater elevation corresponding to the risk category and MRI, in ft (m)

$SWEL_{100}$ = Stillwater elevation for the 100-year MRI, in ft (m)

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T_p = Wave period corresponding to the wave height, in sec (s)
V = Design flood velocity, in ft/s (m/s)
V_{max} = Maximum velocity of water, in ft/s (m/s)
V_w = Volume of displaced water, in ft^3 (m^3)
W = Nondimensional parameter

W_{debris} = Minimum debris weight, in lb (kN)
$W_{lateral}$ = Maximum total lateral wind load on the structure, in lb (kN)
W_{uplift} = Maximum total vertical uplift wind load on the structure, in lb (kN).

Z_{datum} = Elevation of mean water level based on local datum, in ft (m)

z = Depth below design stillwater flood elevation, in ft (m)
α_V = Vertical angle between nonvertical surface and the horizontal
α_H = Horizontal angle between the direction of wave approach and the vertical surface

$\alpha*$ = Impulsive wave pressure coefficient
ϕ_m = Force coefficient
ρ = Mass density of water, in lb s^2/ft^4 (kg/m^3)
Δ_{SLR} = Relative sea level change for coastal sites in ft (m)

γ_w = Specific weight of water, in lb/ft^3 (kN/m^3)
η^* = Height in ft (m), measured above the design stillwater flood elevation, below which the wave pressure is assumed to act, or the minimum height at which the wave pressure equals zero

μ = Coefficient of sliding friction at slip plane being considered between structure on shallow foundations and subgrade

5.3 DESIGN REQUIREMENTS

5.3.1 Flood Hazard Area

For Risk Categories II, III, and IV structures, the Flood Hazard Area shall be the 500-year floodplain designated as the Special Flood Hazard Area and the Shaded X-Zone. For Risk Category I structures, the Flood Hazard Area shall be the 100-year floodplain designated as the Special Flood Hazard Area.

5.3.2 Design Loads

Structural systems of buildings or other structures located within the Flood Hazard Area shall be designed, constructed, connected, and anchored to resist the loads associated with the design flood as defined in this chapter.

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5.3.3 Design Stillwater Flood Depth

The design stillwater flood depth, d_f, in ft (m) shall be determined in accordance with Equation (5.3-1):

$$d_f = (SWEL_{MRI} - G_e) + \Delta_{SLR} \quad (5.3\text{-}1)$$

where

$SWEL_{MRI}$ = Stillwater elevation corresponding to the risk category and MRI defined in Table 5.3-1 provided by a flood hazard study adopted by the Authority Having Jurisdiction, in ft (m). Where the stillwater elevation for a given MRI is not provided in the flood hazard study, the 100-year stillwater elevation shall be scaled to the required MRI per Section 5.3.3.1,

G_e = Elevation of grade at the building or other structure inclusive of effects of erosion in ft (m), per Section 5.3.5, and

Δ_{SLR} = Relative sea level change for coastal sites in ft (m); see Section 5.3.4. Δ_{SLR} shall not be taken as less than 0.

5.3.3.1 Stillwater Elevation Determination When MRI Data Not Available

Where MRI data is not available, $SWEL_{MRI}$ shall be determined according to Equation (5.3-2):

$$SWEL_{MRI} = C_{MRI}\,(SWEL_{100} - Z_{datum}) + Z_{datum} \quad (5.3\text{-}2)$$

where

$SWEL_{100}$ = Stillwater elevation for the 100-year MRI provided by a flood hazard study adopted by the Authority Having Jurisdiction in ft (m),

C_{MRI} = Flood scale factor associated with the MRI from Table 5.3-1 for different locations, and

Z_{datum} = Elevation of mean water level based on local datum, in ft (m). For riverine sites, Z_{datum} shall be taken as the annual high-water level. Z_{datum} shall be permitted to be taken as zero for coastal sites. Values for $SWEL_{100}$, $SWEL_{MRI}$, and G_e shall all reference the same local datum.

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Table 5.3-1. Design Flood MRI Scaling Factors.

Risk Category	MRI (year)	Annual Exceedance Probability (AEP)	C_{MRI} Gulf of Mexico Coastal Sites[1]	C_{MRI} All Other Coastal Sites[1]	C_{MRI} Great Lakes Sites[2]	C_{MRI} Riverine Sites
I	100	1.00%	1.00	1.00	1.00	1.00
II	500	0.20%	1.35	1.25	1.15	1.35
III	750	0.13%	1.45	1.35	1.20	1.45
IV	1,000	0.10%	1.50	1.40	1.25	1.50

[1]Gulf Coast site scale factors are for coastlines of Texas, Louisiana, Mississippi, Alabama, and Florida west of 80.75 degrees W. All other coastlines shall be taken as Other.

[2]If flood loading is being considered on other lakes, the scale factors for riverine sites shall be used.

5.3.4 Effects of Relative Sea Level Change

The effects of relative sea level change shall be included in the calculation of flood conditions and flood loads for sites whose flooding comes from coastal sources. A project lifecycle of not less than 50 years shall be used for this quantification. The minimum rate of relative sea level change shall be the historically recorded sea level change rate for the site over a 50-year period. The increase in relative sea level during the project lifecycle of the structure shall be added to the design stillwater flood elevation as required by Section 5.3.3.

5.3.5 Erosion

The effects of erosion shall be included in the calculation of flood conditions and flood loads. The effects of erosion need not exceed the depth of non-erodible strata.

5.3.6 Flood Velocity

5.3.6.1 Flood Velocity in Coastal Areas

For coastal areas, the velocity of water V in the absence of neighboring structures shall be obtained by one of the following three methods: (1) by using Equation (5.3-4), (2) by numerical modeling, or (3) by laboratory testing (physical modeling). When Method 2 or 3 are used, design flood parameters shall be determined using site-specific studies in accordance with Section 5.3.11.

$$V = C_V\sqrt{g\ d_f} \qquad (5.3\text{-}4)$$

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where

V = Design flood velocity, in ft/s (m/s),

g = Acceleration due to gravity, 32.2 ft/s^2 (9.81 m/s^2),

d_f = Design stillwater flood depth, in ft (m), and

C_V = Velocity coefficient, taken as 0.5.

The maximum velocity of water, $V_{max,}$ for coastal areas need not be greater than C_{VMAX} *10 ft/s (C_{VMAX} * 3.05 m/s), where C_{VMAX} is the coefficient obtained from Table 5.3-2 used to scale to the maximum velocity.

Table 5.3-2. Design Flood MRI and Scaling Factors for Maximum Velocity.

Risk Category	All Coastal Sites C_{VMAX}
I	1.00
II	1.35
III	1.45
IV	1.50

5.3.6.2 Flood Velocity in Riverine Areas

For riverine areas, the average velocity of water V shall be obtained by one of the following four methods: (1) from a flood hazard study, (2) by analytical methods using open channel flow hydraulics, (3) by numerical modeling, or (4) by laboratory testing (physical modeling). When Method 2, 3 or 4 are used, design flood parameters shall be determined using the site-specific hazard procedures of Section 5.3.11.

5.3.7 Wave Effects

The effects of waves shall be included for both V-Zones and A-Zones. In areas subjected to riverine flooding only, the effects of waves are permitted to be neglected.

5.3.7.1 Wave Height

The design wave height H_{design} at the site in ft (m) shall be obtained by one of the following four methods: (1) by assuming depth-limited breaking wave conditions, (2) from a flood hazard study, (3) by numerical modeling, or (4) by laboratory testing (physical modeling). When Method 3 or 4 are used, design flood parameters shall be determined using the site-specific hazard procedures of Section 5.3.11.

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If Method 1 is used, the wave shall be considered a breaking wave for the calculation of scour depths in Section 5.3.8 and wave loads in Section 5.4.4. For Method 1, the design wave height H_{design} shall equal the breaking wave height H_b in ft (m) and shall be determined by

$$H_{design} = H_b \quad (5.3\text{-}5)$$

where H_b is calculated as follows:

$$H_b = C_{br} d_f \quad (5.3\text{-}6)$$

where

d_f = Design stillwater flood depth, in ft (m), and

C_{br} = Wave height coefficient for depth-limited breaking taken as 0.78.

If Method 2, 3, or 4 is used, the design wave height H_{design} in ft (m) for the calculation of scour depths in Section 5.3.8 and wave loads in Section 5.4.4 shall be determined by

$$H_{design} = H_c \quad (5.3\text{-}7)$$

where H_c is calculated as follows:

H_c = Controlling wave height in ft (m) from Method 2, 3, or 4, taken as

$$H_c = 1.6\, H_s \quad (5.3\text{-}8)$$

where H_s = Significant wave height.

When wave heights are not known at the site, but are known at the shoreline, the wave heights are permitted to be transformed to the site accounting for obstructions and depth limitations.

If the controlling wave height is specified by a 100-year design flood, then the controlling wave height shall be adjusted to the controlling wave height corresponding to the MRI design flood event using Table 5.3-3 such that $H_{cMRI} = C_{HC} * H_{c100}$.

If H_{design} at the site is equal to or exceeds H_b from Eq. (5.3-6), then the wave shall be breaking and $H_{design} = H_b$.

Table 5.3-3 Design Flood MRI and Scaling Factors for Controlling Wave Height.

Risk Category	All Coastal Sites C_{HC}
I	1.00
II	1.30
III	1.35
IV	1.40

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5.3.7.2 Wave Period and Wavelength.

The wave period T_p in sec (s) corresponding to the wave height shall be obtained by one of the following four methods: (1) by using Equation (5.3-9), (2) from a flood hazard study, (3) by numerical modeling, or (4) by laboratory testing (physical modeling). When Methods 3 or 4 are used, design flood parameters shall be determined using site-specific studies in accordance with Section 5.3.11.

$$T_p = C_T \sqrt{\frac{H_{design}}{g}} \tag{5.3-9}$$

where

T_p = Wave period corresponding to the wave height, in sec (s),

C_T = Wave period coefficient equal to 12.1, and

g = Acceleration due to gravity, 32.2 ft/s^2 (9.81 m/s^2).

The wavelength, L, in ft (m) shall be calculated by

$$L = \frac{gT_p{}^2}{2\pi}\left(1 - e^{-\left(\frac{2\pi}{T_p}\sqrt{\frac{d_f}{g}}\right)^{\frac{5}{2}}}\right)^{\frac{2}{5}} \tag{5.3-10}$$

5.3.8 Scour

Scour shall be calculated by using either the procedures outlined in Sections 5.3.8.1 and 5.3.8.2. Scour shall be considered for surfaces subject to hydrodynamic forces above the non-erodible strata.

EXCEPTION: Analysis of scour is not required if soils adjacent to structural foundations are non-erodible or protected against scour by structures designed for anticipated flood loads.

5.3.8.1 Scour at Walls

Scour depth at the exposed face of walls shall be calculated in accordance with Section 5.3.8.1.1, for scour due to nonbreaking waves, or in accordance with Section 5.3.8.1.2, for scour due to breaking waves. Waves shall be evaluated per Section 5.3.7. A structural element with a ratio of the design stillwater flood depth to the lateral dimension facing the wave less than three shall be considered to act as a wall. Tightly spaced piles or columns where the clear distance between piles or columns is less than one half of the lateral dimension of an individual pile or column facing the wave shall be considered to act as a wall.

5.3.8.1.1 Scour Due to Nonbreaking Waves

The maximum scour depth S_m in ft (m) at walls for nonbreaking waves shall be calculated by Equation (5.3-11):

$$S_m = \frac{0.25\,H_{design}}{\left[\sinh\left(\frac{2\pi d_f}{L}\right)\right]^{1.35}} \quad (5.3\text{-}11)$$

where

d_f = Design stillwater flood depth as defined in Section 5.3.3,

H_{design} = Design wave height as defined in Section 5.3.7,

L = Wavelength in ft (m) as defined in Section 5.3.7, and

S_m Need not be taken greater than S_m as calculated in Section 5.3.8.1.2.

5.3.8.1.2 Scour Due to Breaking Waves

The maximum scour depth, S_m, in ft (m) at walls for breaking waves shall be calculated by Equation (5.3-12):

$$S_m = H_{design} \quad (5.3\text{-}12)$$

where H_{design} = breaking wave height H_b in ft (m) as defined in Section 5.3.7.

5.3.8.2 Scour at Vertical Piles and Columns

The scour depth, S_m, at the base of a single vertical pile or column inundated at the time of flooding shall be calculated by Equation (5.3-13). Tightly spaced piles shall be considered to act as a wall per Section 5.3.8.1.

$$S_m = 2.0\,D \quad (5.3\text{-}13)$$

where D = pile or column diameter, in ft (m) for circular sections, or for a square pile or column, 1.4 times the width of the pile or column in ft (m).

Scour of fully embedded piles (i.e., no exposed length of pile above ground) shall only be considered if scour is determined to extend below the bottom of the overlying structure, including the pile cap(s). Scour shall be calculated in accordance with Section 5.3.8.1 for overlying walls and in accordance with Section 5.3.8.2 for overlying columns.

5.3.9 Debris

Risk Categories II, III, and IV structures shall be designed for debris impact and debris damming in accordance with this section where the Design Stillwater Flood Depth (d_f) is greater than 3 ft (0.91 m).

5.3.9.1 Debris Impact.

Structures within the Flood Hazard Area shall be designed for debris impact loads as determined by Section 5.4.5.1. Debris impact loads shall be considered in any direction and at heights as required per Section 5.4.5.2. Debris impact loads need not be considered on multiple structural elements simultaneously.

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EXCEPTIONS:

1. Where a site-specific study provides flow directions, debris impacts need only be considered from the directions shown in the site-specific study +/- 22.5 degrees.

2. For riverine sites, debris strikes need only be considered from the upstream direction with a strike direction of +/- 22.5 degrees from the primary direction of flow.

3. Design for debris impact is not required for detached one- and two-family dwellings.

4. Design for debris impact is not required for Risk Category II structures outside of the Special Flood Hazard Area.

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5.3.9.1.1 Debris Impact Objects

Buildings and other structures as required in Section 5.3.9 shall be designed for debris impact loads from floating debris. Debris objects considered shall be determined based on risk category, flow depth, and structure component type in accordance with Table 5.3-4. A site hazard assessment per Section 5.3.9.1.2 shall be used to determine the applicability of debris strikes as required. Any ship or barge exceeding 88,000 lb (391 kN), based on the Lightweight Tonnage (LWT) plus 30% of Deadweight Tonnage (DWT), shall be considered as Extraordinary Debris.

Table 5.3-4 Debris Type Applicability.

Debris Type	Applicable Risk Categories	Threshold Depth (ft)[1]	Impact on columns, piles, bearing walls and transfer beams	Impact on non-load bearing elements[2]
Passenger Vehicles	RC II/III/IV	3 ft (0.91 m)	Yes	Yes
Small Vessels	RC II/III/IV	3 ft (0.91 m)	Yes[3]	Yes[3]
Wood Poles	RC III/IV	3 ft (0.91 m)	Yes	Yes
Shipping Containers	RC III/IV	3 ft (0.91 m)	Yes[3]	n/a
Ships/barges	RC III/IV	6 ft (1.8 m)	Yes[3]	n/a
Extraordinary Debris[3]	RC IV	12 ft (3.7 m)	Yes[3 4]	n/a

[1]Threshold depth is the minimum Design Stillwater Flood Depth required for a debris object to be considered for design.

[2]Elements that are part of a dry floodproofing system, including temporary flood barriers, as defined by ASCE 24.

[3] As required by Section 5.3.9.1.2.

[4]See Section 5.3.9.1.3 for applicable impacted elements.

5.3.9.1.2 Site Hazard Assessment for Localized Marine Debris, Shipping Containers, Ships, Small Vessels, and Barges

Nearby container yards, ports/harbors, marinas, or other sources shall be evaluated as potential debris origins for shipping containers, ships, small vessels, and barges according to the following procedure.

Debris travel from their source location shall be based on a two-step process. Debris shall be assumed to travel over water, beach or open land and shall travel a minimum of a 10,000 ft (3.03 km) radius from the source or until rougher land surface exists. Then, from any point within the initial debris spread area the debris can travel an additional distance into a developed environment in accordance with Table 5.3-5.

Table 5.3-5. Debris Travel in Urban Environment.

Debris Type	Travel distance in moderate density environment *	Travel distance in heavy density environment [1]
Small vessels	2,000 ft (604 m)	1,000 ft (304 m)
Shipping Containers	2,000 ft (604 m)	1,000 ft (304 m)
Ships/barges	1,000 ft (302 m)	500 ft (152 m)
Extraordinary debris	1,000 ft (302 m)	500 ft (152 m)

*Heavy density environments are areas where the density of structures with a height of at least 75% of the design flood depth is greater than 30% of plan area within the Flood Hazard Area. All other areas shall be considered moderate density.

EXCEPTION: Debris impact loads from shipping containers, ships, and barges need not be considered where the flood depth at the structure is less than the draft of the debris object plus 2.0 ft (0.61 m), or where the path of the debris object is blocked by a structure or topographic feature that results in inadequate draft.

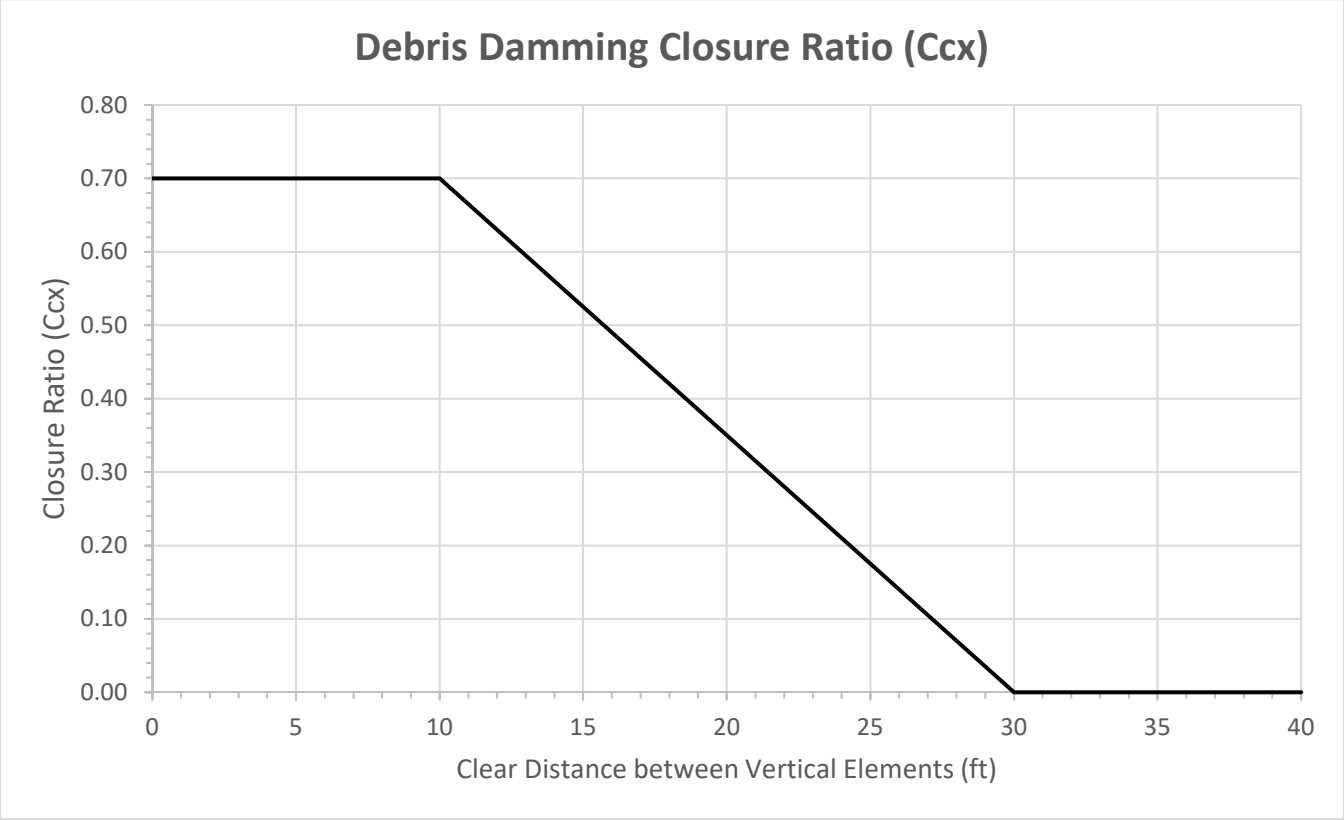
5.3.9.1.3 Extraordinary Debris Impact Loading

As required by Section 5.3.9.1.1 all perimeter columns, bearing walls and transfer beams shall be designed for the largest ship or barge exceeding 88,000 lb (391 kN) as required by Section 5.4.5.3.

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5.3.9.2 Debris Damming

The effects of debris damming shall be applied to structures that allow the free passage of flood waters through the building footprint, including structures with breakaway walls, as required by this section. A minimum closure ratio (C_{cx}) shall be determined in accordance with Figure 5.3-1 based on the clear spacing between structural columns, piles and/or walls perpendicular to the flow direction. The closure ratio shall be used to determine the drag load on vertical structural elements for hydrodynamic loading as required in Section 5.4.3.



Note: To convert to SI units multiply feet by 0.305 to get clear distance in meters.

Figure 5.3-1. Debris Damming Closure Ratio (C_{cx}).

5.3.10 Loads on Breakaway Walls.

Where required by ASCE/SEI 24 to break away, walls and partitions, including their connections to the structure, shall be designed in accordance with this section. The wall shall be designed to resist the following loads acting perpendicular to the plane of the wall:

1. The wind load specified in this standard,
2. The seismic load specified in Chapter 12
3. The lateral earth pressure specified in Chapter 3, and
4. 16 lb/ft^2 (0.76 kN/m^2).

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If the largest of the loads above is less than the 100-year flood load, the wall shall be designed to fail during the 100-year flood condition.

The structure and its foundation shall be designed against collapse, permanent lateral displacement, and other structural damage due to the expected failure forces as walls break away.

5.3.11 Site-Specific Studies

If site-specific hydrologic and hydraulic studies are used to estimate effects from floods, they shall be conducted in accordance with accepted engineering practice. Where a site-specific study is performed, a report shall be prepared and submitted to the Authority Having Jurisdiction. The report shall provide the proposed value of each parameter shown in Table 5.3-6 and the basis for these values. Maximum allowable reductions in velocity, wave height, and wave period at the site are given in Table 5.3-6. The reduction in the velocity and the design wave height and period shall be based on the velocity, wave height, and period computed from Section 5.3.6 and Section 5.3.7, respectively.

Table 5.3-6. Maximum Allowable Reductions for Site-Specific Studies.

Hazard	Allowable Reduction with Peer Review	Allowable Reduction without Peer Review
Velocity, *V*	30%	20%
Wave height, *H*	30%	20%
Wave period, *T*	30%	20%

5.3.12 Performance-Based Design.

Flood design of buildings and other structures using performance-based procedures shall be permitted subject to the approval of the Authority Having Jurisdiction. The performance-based flood design procedures used shall, at a minimum, conform to Section 1.3.1.3.

5.4 LOADS DURING FLOODING

5.4.1 Load Basis

In the Flood Hazard Areas, the flood loads used for structural design shall be based on the Design Flood.

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5.4.2 Hydrostatic Loads

Hydrostatic loads caused by a depth of water to the design stillwater flood elevation shall be applied over all surfaces contacted, both above and below ground level.

Hydrostatic forces shall be calculated in accordance with Sections 5.4.2.1 and 5.4.2.2. The hydrostatic pressures shall be calculated utilizing basic fluid mechanics by applying pressures perpendicular to wetted surfaces proportional to the depth of water such that

$$p_h = \gamma_w z \qquad (5.4\text{-}1)$$

where

p_h = Hydrostatic pressure at a given depth z, in lb/ft^2 (kN/m^2),

γ_w = Specific weight of water, taken as 62.4 lb/ft^3 (9.81 kN/m^3) for freshwater and 64 lb/ft^3 (10.03 kN/m^3) for saltwater, and

z = Depth below design stillwater flood elevation, in ft (m).

Reduced hydrostatic uplift and lateral loads on surfaces of enclosed spaces below the design stillwater flood elevation shall apply only if provision is made for entry and exit of floodwater.

Hydrostatic loads below grade shall be calculated assuming the soils are fully saturated and in accordance with Sections 5.4.2.1 and 5.4.2.2 unless the degree of soil saturation and below grade porewater pressures during a flood event are determined in accordance with Section 5.4.2.3.

5.4.2.1 Vertical Hydrostatic Force

Structures or portions of a structure submerged below the design stillwater flood elevation and with enclosed air in spaces where walls are not designed to break away or allow for entry and exit of floodwaters shall be designed for buoyancy. Buried portions of structures shall be designed assuming the soils beneath the structure are fully saturated unless otherwise determined per Section 5.4.2.3.

The vertical uplift force caused by buoyancy for determination of structure uplift shall be applied at the centroid of the submerged volume of the structure, and shall be calculated using Equation (5.4-2):

$$F_B = \gamma_w V_w \qquad (5.4\text{-}2)$$

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where

F_B = Uplift force caused by buoyancy, in lb (kN),

γ_w = Specific weight of water, taken as 62.4 lb/ft^3 (9.81 kN/m^3) for freshwater and 64 lb/ft^3 (10.03 kN/m^3) for saltwater, and

V_w = Volume of displaced water, in ft^3 (m^3).

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5.4.2.2 Lateral Hydrostatic Force

The lateral force, F_h, caused by the hydrostatic pressure on one side of a vertical wall per unit width, lb/ft (kN/m) shall be calculated by Equation (5.4-3):

$$F_h = (1/2)\ \gamma_w\ d_f^2 \qquad (5.4\text{-}3)$$

5.4.2.3 Seepage

Numerical modeling for analysis of transient seepage is permitted to evaluate the porewater pressures on structures for conditions before, during, and after a flood event in lieu of using hydrostatic pressures as described in Sections 5.4.2.1 and 5.4.2.2. Permeability of soils and impermeable cutoffs (e.g., concrete slabs, below-grade walls) shall be included in the seepage analysis. The seepage analysis shall be based on a geotechnical investigation report that includes test data for soil permeability.

5.4.3 Hydrodynamic Loads

5.4.3.1 Drag Force on Components

The hydrodynamic drag force, exerted by moving water on structural components immersed in the flow and buildings immersed in the flow, shall be determined by Equation (5.4-4):

$$F_{drag} = (1/2)\ \rho\ C_d\ V^2\ h\ (b + C_{cx}\ s) \qquad (5.4\text{-}4)$$

where

ρ = Mass density of water, in lb s^2/ft^4, taken as 1.94 lb s^2/ft^4 (1000 kg/m^3) for fresh water and 1.99 lb s^2/ft^4 (1027 kg/m^3) for seawater,

C_d = Drag coefficient for submerged objects subjected to currents, defined in Table 5.4-1,

V = Design flood velocity, in ft/s (m/s),

h = Submerged height of column or wall above its foundation or structural floor level, in ft (m),

b = Width of column or wall, perpendicular to the direction of flow considered, in ft (m),

C_{cx} = Debris damming closure ratio as determined in Section 5.3.9.2, and

s = Average clear spacing of column or wall to the adjacent column or wall, in ft (m). For corner columns, half the clear distance shall be used.

For geometries not provided in Table 5.4-1 and for structures with openings, the dynamic effects of moving water shall be determined by a detailed analysis utilizing concepts of fluid mechanics.

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Table 5.4-1. Drag Coefficients for Structural Components.

Structural Element Section	Drag Coefficient, C_d
Round column or equilateral polygon with six sides or more	1.2
Rectangular column of at least 2:1 aspect ratio with longer face oriented parallel to flow	1.6
Free-standing wall submerged parallel to flow	1.6
Square or rectangular column with longer face oriented perpendicular to flow	2.0
Triangular column pointing away from flow	2.0
Wall or flat plate, normal to flow	2.0
Diamond-shape column, pointed into the flow (based on face width, not projected width)	2.5
Rectangular beam, normal to flow	2.0
I, L, and channel shapes	2.0
Structural components with debris damming per Section 5.3.9.2	2.0

5.4.3.2 Drag Force on Lateral Force Resisting System.

The building lateral force resisting system shall be designed to resist the overall drag forces on the structure. For enclosed buildings the lateral force shall be determined based on Equation 5.4-5:

$$F_{drag} = (1/2)\,\rho\, C_d\, V^2\, B\, d_f \qquad (5.4\text{-}5)$$

ρ = Mass density of water, in lb s^2/ft^4, taken as 1.94 lb s^2/ft^4 (1000 kg/m^3) for fresh water and 1.99 lb s^2/ft^4 (1027 kg/m^3) for seawater,

C_d = Drag coefficient for per Table 5.4-2 for Rectilinear Buildings and Structures,

V = Design flood velocity, in ft/s (m/s),

B = Overall width of building perpendicular to the flow direction, in ft (m), and

d_f = Design flood depth per Section 5.3.3, in ft (m).

When the design flood depth d_f exceeds the height of the structure, then d_f in Equation 5.4-5 is replaced by the height of the structure.

For open buildings or buildings with breakaway walls as defined by Section 5.3.10, the building lateral force resisting system shall be designed to resist the summation of the drag loads of each exposed vertical and horizontal element as required by Section 5.4.3.1 using Equation 5.4-4. The effects of debris damming shall be considered on the side of the structure exposed to the flow direction, considering damming on any two adjacent bays or a minimum of a 50 ft (15.2 m) width, whichever produces the largest base shear.

Table 5.4-2. Drag Coefficients for Rectilinear Buildings and Structures.

Ratio of structure width to design stillwater flood depth* B/d_f	Drag Coefficient, C_d
≤ 12	1.25
≥ 120	2.0

*Linear interpolation shall be used for intermediate values of b/d_f. Where building setbacks occur, drag coefficients shall be determined for each portion of constant width.

5.4.4 Wave Loads.

Wave loads shall be determined by one of the following two methods: (1) by using the analytical procedures outlined in this section, or (2) by more advanced analytical procedures, numerical modeling procedures, or physical modeling procedures. If more advanced procedures are used to determine wave loads, any reduction in wave loads from those in this section shall not exceed 20 percent without conducting a peer review. In no case shall a reduction of more than 30 percent be permitted.

Waves shall be evaluated per Section 5.3.7.

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For the calculation of wave loads per Section 5.4.4, a structural element with the ratio of the design stillwater flood depth to the lateral dimension facing the wave that is greater than or equal to three shall be considered a pile or column, and wave loads on the member shall be calculated per Section 5.4.4.1. A structural element with a ratio of the design stillwater flood depth to the lateral dimension facing the wave that is less than three shall be considered to act as a wall, and wave loads on the element shall be calculated per Section 5.4.4.2. Tightly spaced piles or columns where the clear distance between piles or columns is less than one half of the lateral dimension of an individual pile or column facing the wave shall be considered to act as a wall.

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5.4.4.1 Wave Loads on Vertical Piles and Columns

Lateral wave loads on vertical piles or columns shall be calculated using the procedures described in Sections 5.4.4.1.1 for nonbreaking waves and Section 5.4.4.1.2 for breaking waves. Broken wave loads shall be treated similar to nonbreaking wave loads.

5.4.4.1.1 Nonbreaking Wave Loads on Vertical Piles and Columns

Equations for nonbreaking wave loads on vertical piles and columns shall be considered applicable when the nondimensional parameter $W = C_M D/(C_D H_{design})$ is less than or equal to 1.0, where C_M is an inertia coefficient, taken as 2.0 for round piles or columns and taken as 2.5 for square piles or columns. When W is greater than 1.0, then the wave load shall be calculated using the requirements of Section 5.4.4.2.1.

When *W is* less than or equal to 1.0, the maximum net lateral force resulting from a nonbreaking wave F_m in lbs (kN) acting on a vertical pile or column shall be calculated by Equation (5.4-6) and applied at the design stillwater flood elevation:

$$F_m = \phi_m C_D \gamma_w H_{design}^2 D \qquad (5.4\text{-}6)$$

where

ϕ_m = Force coefficient, taken as 0.5 for round or square piles and round or square columns,

C_D = Wave drag coefficient, shall be taken as 0.7 for round piles or columns and shall be taken as 2.25 for square or rectangular piles or columns,

H_{design} = Design wave height in ft (m) as defined in Section 5.3.7, and

D = Pile or column diameter, in ft (m) for circular sections, or the largest projected width of the pile or column in ft (length of plan diagonal) (m) for a square or rectangular pile or column.

5.4.4.1.2 Breaking Wave Loads on Vertical Piles and Columns

The maximum net lateral force F_{bw} resulting from a breaking wave acting on a vertical pile or column shall be assumed to act at the design stillwater flood elevation and shall be calculated by Equation (5.4-7):

$$F_{bw} = \phi_m C_{bw} \gamma_w H_{design}^2 D \quad (5.4\text{-}7)$$

where

ϕ_m = Force coefficient, taken as 0.5 for round or square piles and round or square columns,

C_{bw} = Coefficient for breaking waves, shall be taken as 1.75 for round piles or columns and shall be taken as 2.25 for square or rectangular piles or columns. H_{design} = design wave height in ft (m) as defined in Section 5.3.7, and

D = Pile or column diameter, in ft (m) for circular sections, or the largest projected width of the pile or column in ft (length of plan diagonal) (m) for a square or rectangular pile or column.

5.4.4.2 Lateral Wave Loads on Walls

Lateral nonbreaking and broken wave loads on non-elevated vertical walls shall be calculated using the procedures described in Section 5.4.4.2.1. Lateral breaking wave loads on non-elevated vertical walls shall be calculated using the procedures described in Section 5.4.4.2.2. Lateral wave loads shall be modified for nonvertical walls and obliquely incident waves as specified in Section 5.4.4.2.3 and Section 5.4.4.2.4, respectively. Wave loads on elevated walls shall be calculated using the procedures described in Section 5.4.4.2.5.

As required in Section 5.5, the wave-induced hydrodynamic pressure distribution and forces in this section shall be combined with hydrostatic loads, in accordance with Section 5.4.2, and hydrodynamic loads, in accordance with Section 5.4.3. Hydrostatic or hydrodynamic loads shall be considered for conditions in which the design stillwater flood depth is not equal on both sides of the wall and/or a current affects the structure in accordance with the combination of flood load cases per Section 5.5.

5.4.4.2.1 Lateral Nonbreaking Wave Loads on Non-elevated Vertical Walls

The pressure distribution due to a nonbreaking wave on a vertical wall is shown in Figure 5.4-1 and shall be calculated using Equations (5.4-8) to (5.4-11):

$$\eta^* = 1.5 H_{design} \quad (5.4\text{-}8)$$

$$p_1 = [0.6 + 0.5 \left(\frac{4\pi d_f / L}{\sinh (4\pi d_f / L)} \right)^2] \gamma_w H_{design} \quad (5.4\text{-}9)$$

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$$p_2 = \begin{cases} \left(1 - \frac{h_c}{\eta^*}\right) p_1 & \text{for } \eta^* > h_c \\ 0 & \text{for } \eta^* \leq h_c \end{cases} \quad (5.4\text{-}10)$$

$$p_3 = \left(\frac{1}{cosh\,(2\pi d_f/L)}\right) p_1 \quad (5.4\text{-}11)$$

where

η^*= Height in ft (m), measured above the design stillwater flood elevation, below which the wave pressure is assumed to act, or the minimum height at which the wave pressure equals zero,

H_{design} = Design wave height as defined in Section 5.3.7, in ft (m),

p_1 = Pressure at the design stillwater flood elevation, in lb/ft^2 (kN/m^2),

p_2 = Pressure at the top of the vertical wall or structure, in lb/ft^2 (kN/m^2),

p_3 = Pressure at the eroded ground elevation, in lb/ft^2 (kN/m^2),

d_f = Design stillwater flood depth as defined in Section 5.2, in ft (m),

h_c = Height to the top of the vertical wall or structure above the design stillwater flood elevation, in ft (m), and

L = Wavelength as specified in Section 5.3.7, in ft (m).

The parameters $\left(\frac{4\pi df/L}{sinh\,(4\pi df/L)}\right)^2$ and $\left(\frac{1}{cosh\,(2\pi d_f/L)}\right)$ range between 0 and 1 and may conservatively be taken as equal to 1.0 in Equations (5.4-9) and (5.4-11).

The lateral wave-induced force per unit length on the vertical wall or structure in lb/ft (kN/m) shall be calculated using Equation (5.4-12):

$$F_t = \begin{cases} \left(\frac{1}{2}(p_1 + p_2)h_c + \frac{1}{2}(p_1 + p_3)d_f\right) & \text{for } \eta^* > h_c \\ \left(\frac{1}{2}p_1(\eta^*) + \frac{1}{2}(p_1 + p_3)d_f\right) & \text{for } \eta^* \leq h_c \end{cases} \quad (5.4\text{-}12)$$

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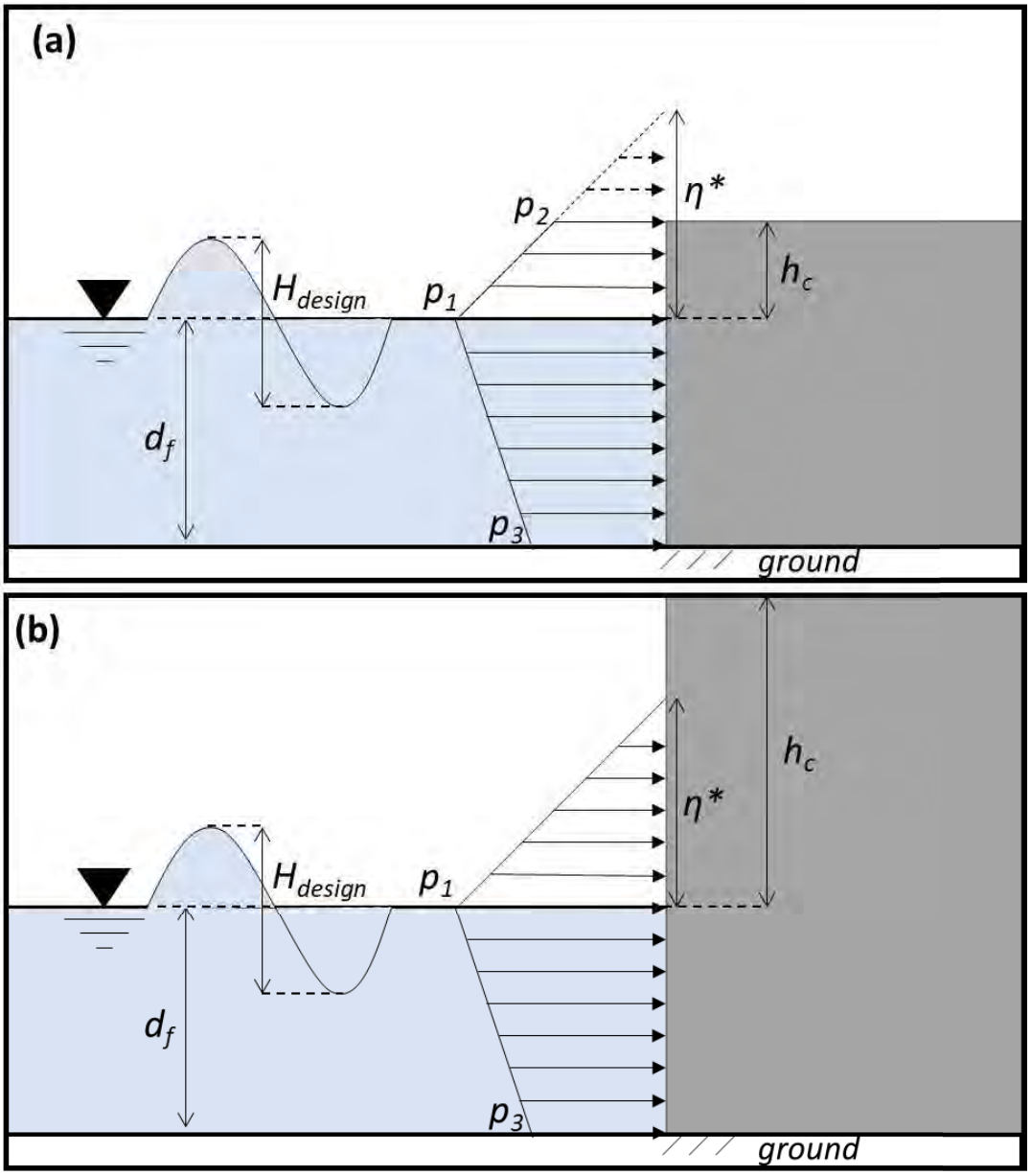


Figure 5.4-1. Normally incident wave pressures against a non-elevated vertical wall: (a) $\eta^* > h_c$; (b) $\eta^* \leq h_c$.

5.4.4.2.2 Lateral Breaking Wave Loads on Non-elevated Vertical Walls

The lateral breaking wave force per unit length on a vertical wall, F_{BRK} in lb/ft (kN/m) shall be calculated by Equation (5.4-13):

$$F_{BRK} = \begin{cases} \left(\frac{1}{2}(p_{1B} + p_2)h_c + \frac{1}{2}(p_{1B} + p_3)d_f\right) & \text{for } \eta^* > h_c \\ \left(\frac{1}{2}p_{1B}(\eta^*) + \frac{1}{2}(p_{1B} + p_3)d_f\right) & \text{for } \eta^* \leq h_c \end{cases} \quad (5.4\text{-}13)$$

where

p_{1B} = Breaking wave pressure acting at the design stillwater flood elevation in lb/ft^2 (kN/m^2) calculated by Equation (5.4-14):

$$p_{1B} = [0.6 + 0.5\left(\frac{4\pi d_f/L}{sinh\,(\pi 4 d_f/L)}\right)^2 + \alpha^*]\gamma_w H_{design} \quad (5.4\text{-}14)$$

where

α^*= Impulsive wave pressure coefficient, which shall be taken as 0.8, and

H_{design} = Design wave height in ft (m) as defined in Section 5.3.6.

In Equation (5.4-13), p_2, p_3, and η^* are calculated as prescribed in Section 5.4.4.2.1, and the parameter $\left(\frac{4\pi df/L}{sinh\,(4\pi df/L)}\right)^2$ may be conservatively taken as 1.

5.4.4.2.3 Lateral Breaking Wave Loads on Nonvertical Walls

Lateral breaking wave forces shall be modified in instances where the walls or surfaces upon which the breaking waves act are nonvertical. The horizontal component of the breaking wave force per unit length on a nonvertical wall, F_{BNV}, in lb/ft (kN/m) shall be calculated by Equation (5.4-15):

$$F_{BNV} = F_{BRK}\,[sin(\alpha_V)]^2 \quad (5.4\text{-}15)$$

where

F_{BNV} = Horizontal component of breaking wave force per unit length on a nonvertical wall, in lb/ft (kN/m),

F_{BRK} = Breaking wave force per unit length on a vertical wall, in lb/ft (kN/m), and

α_V = Vertical angle between nonvertical surface and the horizontal.

5.4.4.2.4 Lateral Breaking Wave Loads from Obliquely Incident Waves

Lateral breaking wave forces shall be modified in instances where waves are obliquely incident. Breaking wave forces from obliquely incident waves shall be calculated by Equation (5.4-16):

$$F_{BOI} = F_{BRK}\,[sin(\alpha_H)]^2 \quad (5.4\text{-}16)$$

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where

F_{BOI} = Horizontal component of obliquely incident breaking wave force in lb/ft (kN/m),

F_{BRK} = Breaking wave force per unit length on a vertical wall, in lb/ft (kN/m), and

α_H = Horizontal angle between the direction of wave approach and the vertical surface.

5.4.4.2.5 Lateral Wave Loads on Elevated Walls

The procedures for determining lateral wave loads on elevated vertical walls due to nonbreaking or breaking waves shall be calculated by modifying the procedures for non-elevated vertical walls outlined in Sections 5.4.4.2.1 and 5.4.4.2.2, respectively, by considering only pressures that act over the vertical surface of the wall. Figure 5.4-2 shows a case when the lowest portion of the wall is above the design stillwater flood elevation (positive air gap) and a case when the design stillwater flood elevation is above the lowest portion of the wall (negative air gap).

The pressure distribution associated with nonbreaking waves interacting with an elevated wall shall be calculated in accordance with Section 5.4.4.2.1, with pressure at the base of the structure p_4 determined by linearly interpolating between p_1 and $p=0$ at η^* (positive air gap) or p_1 and p_3 (negative air gap), using Equation (5.4-17):

$$p_4 = \begin{cases} \left(1 - \frac{a}{\eta^*}\right) p_1, & \text{for } a \geq 0 \\ \left(1 - \frac{|a|}{d_f}\right)(p_1 - p_3) + p_3, & \text{for } a < 0 \end{cases} \qquad (5.4\text{-}17)$$

where a = Air gap between lowest supporting horizontal structural member of lowest above grade floor and the design stillwater flood elevation, in ft (m).

The total lateral wave-induced force per unit length of the elevated wall in lb/ft (kN/m) shall be calculated by integrating the pressure distribution over the vertical domain of the wall. For conditions in which no wave overtopping occurs, the total lateral force per unit length is given by Equation (5.4-18):

$$F_t = \begin{cases} \left(\frac{1}{2} p_4 (\eta^* - a)\right), & \text{for a} \geq 0 \\ \left(\frac{1}{2} p_1 \eta^* + \frac{1}{2}(p_1 + p_4)(|a|)\right), & \text{for } a < 0 \end{cases} \qquad (5.4\text{-}18)$$

Lateral breaking wave loads on elevated walls shall be calculated in accordance with the above equations, applying the modified p_{1B} instead of p_1 in Equations (5.4-17) and (5.4-18). Modified pressure p_{1B} shall be calculated as described in Section 5.4.4.2.2. Wave loads on elevated nonvertical walls or due to obliquely incident waves shall be modified as described in Sections 5.4.4.2.3 and 5.4.4.2.4, respectively.

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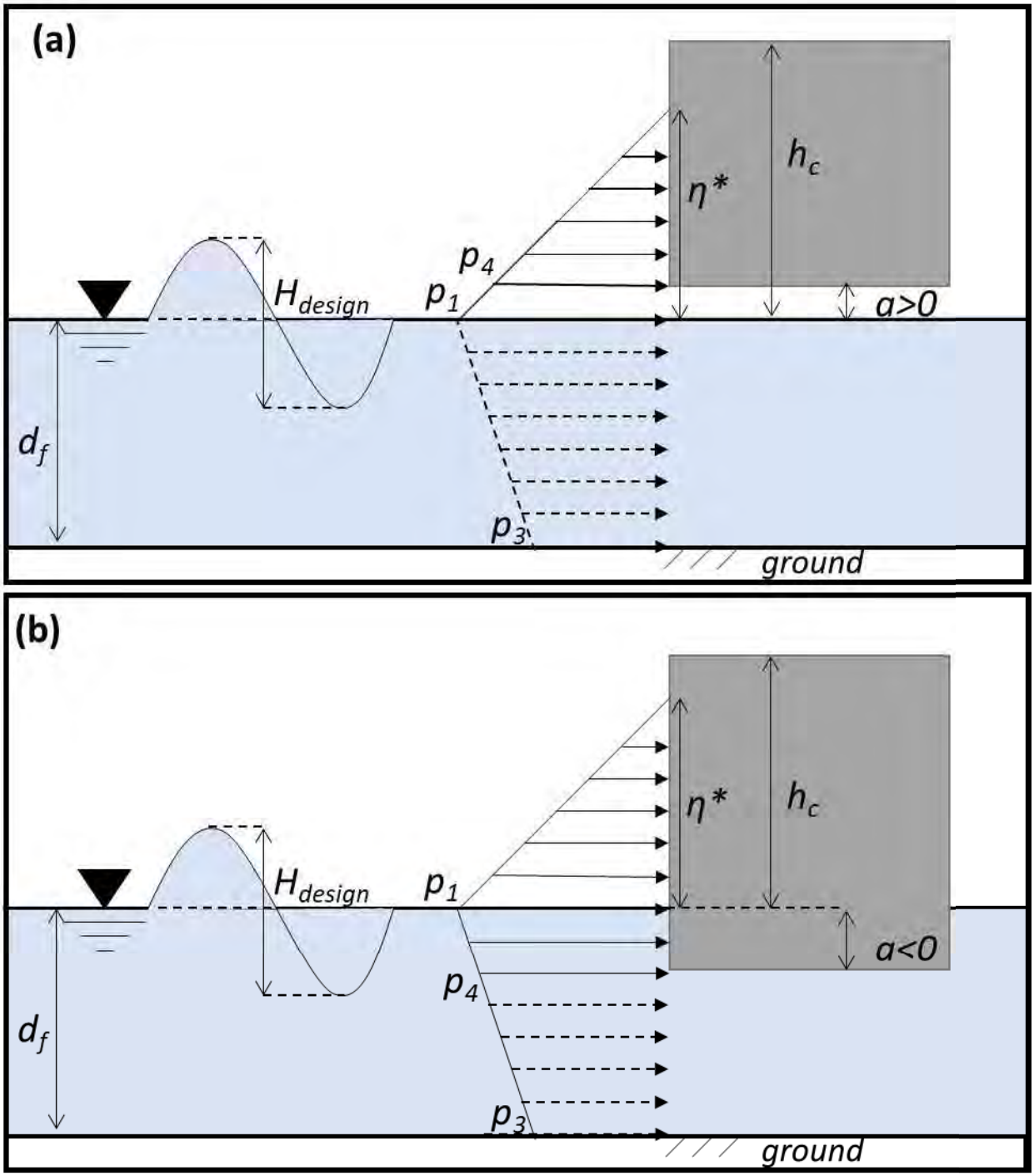


Figure 5.4-2. Normally incident wave pressures on an elevated wall: (a) $a \geq 0$; (b) $a < 0$.

5.4.4.3 Wave Uplift Forces on Elevated Structures and Non-Elevated Structures with Overhangs

Wave uplift forces on elevated structures shall be considered on portions of elevated structures located less than $0.7H_{design}$ above the design stillwater flood elevation.

Wave uplift forces on horizontal overhangs shall be considered when overhangs are positioned within a height of η^* above the design stillwater flood elevation and a solid wall below directs water up against the underside of the overhang.

5.4.5 Debris Impact Loads

Debris impact loads shall be applied as required by Sections 5.3.9.1 and 5.4.5.2 and shall be determined in accordance with this section.

5.4.5.1 Debris Impact Load Determination

Debris impact forces shall be determined by one of the approaches in Sections 5.4.5.1.1 through 5.4.5.1.3. It is permitted to use any of these methods based on their applicability per debris type.

5.4.5.1.1 Simplified Debris Impact Load for Passenger Vehicles or Small Vessels

Debris impact forces for passenger vehicles or small vessels shall be permitted to be determined by applying a static lateral force given by Equation (5.4-19) as the load in lieu of the loads based on the other methods of this section:

$$F_{di} = C_o \ 51{,}000 \text{ (lb)} \qquad (5.4\text{-}19)$$

$$F_{di} = C_o \ 227 \text{ (kN)} \qquad (5.4\text{-}19.\ \text{SI})$$

where C_o = debris orientation coefficient, taken as 0.80.

5.4.5.1.2 Elastic Debris Impact Loads

Debris impact forces, F_{di} in lb (kN) are permitted to be calculated using the elastic debris impact method per Equation (5.4-20):

$$F_{di} = C_o \, V \, C_R C_s \ (k_e \, m_{debris})^{0.5} \quad (5.4\text{-}20)$$

where

C_o = Debris orientation coefficient, taken as 0.80,

V = Design flood velocity as defined in Section 5.3.6, in ft/s (m/s),

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C_R = Debris depth coefficient taken as 1.0 for design flood depths greater than 5 ft (1.52 m) and taken as 0.0 for design flood depths less than 1 ft (0.3 m). Linear interpolation is permitted between design flood depths of 1 ft (0.3 m) and 5 ft (1.52 m), and

C_s = Debris velocity stagnation coefficient per Table 5.4-3. Applicable for nonload-bearing elements on the exterior of buildings along the front face of a building wider than 30 ft (9.14 m). Walls must extend from grade to above the design stillwater flood elevation and be designed for the flood loads of this chapter. For load bearing elements Cs shall be taken as 1.0.

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Table 5.4-3. Debris Velocity Stagnation Coefficient, C_s.

Location on building	Debris velocity stagnation coefficient (C_s)
Within a distance of the greater of 0.2*B* or 10 ft (3.05 m) at edges of building	1.00
Middle 0.6*B* of building	0.50

Notes:

B = Overall width of building perpendicular to flow direction, in ft (m).

k_e = effective stiffness of the impacting debris or the effective lateral stiffness of the impacted structural element(s) deformed by the impact, in lb/ft (kN/m) determined in accordance with Section 5.4.5.2. It is permissible to use the combined elastic stiffness of the debris and the impacted element in series.

m_{debris} = mass of the debris (W_{debris}/g) in lb s^2/ft (kg) determined in accordance with Section 5.4.5.2.

5.4.5.1.3 Alternative Methods of Debris Impact Analysis

Structures or elements of structures are permitted to be modeled as an equivalent single degree of freedom mass-spring system with a nonlinear stiffness that considers the ductility of the impacted structure or element for the dynamic analysis. Alternatively, the structural response shall also be permitted to be calculated based on a work-energy method with nonlinear stiffness that incorporates the ductility of the impacted structure. The velocity used for this analysis shall be $VC_RC_s\ C_o$ as defined by Section 5.4.5.1.2. Debris impact loads as defined in Section 5.3.9.1 and Section 5.4.5.2 shall be applied to the structure to produce the most critical flexural and shear demands.

5.4.5.2 Debris Types and Properties

Debris impact forces specified in Section 5.3.9.1.1 shall have the following minimum application requirements:

1. Wood poles/logs strike in their longitudinal direction centered at any elevation from 3 ft (0.91 m) above grade up to the design stillwater flood depth with an impact area of 1.5 ft (0.46 m) by 1.5 ft (0.46 m).
2. Passenger vehicles strike the structure centered at any elevation from 3 ft (0.9 -m) above grade to 1 ft (0.3 m) below the design stillwater flood depth with an impact area of 5 ft (1.5 m) wide by 2 ft (0.61 m) high.
3. Small vessels strike the structure centered at any elevation from 3 ft (0.91 m) above grade to 3 ft (0.91 m) above the design stillwater flood depth with an impact area of 4 ft (1.2 m) wide by 2 ft (0.61 m) high.
4. The bottom corner rails of shipping containers strike the structure at an elevation from 3 ft above grade to the design stillwater flood depth with an impact area of 1 ft (0.3 m) by 1 ft (0.3 m).

The impact force from ships and barges of less than 88,000 lb (39,916 kg) lightweight tonnage (LWT) shall be determined in accordance Section 5.4.5.1.2 or 5.4.5.1.3. The debris strike shall be applied in the longitudinal direction of the debris. The minimum mass considered shall be the mass of the largest expected ship or barge required by Section 5.3.9.1.2. The stiffness of the ship or barge shall be estimated based on the length, width, and construction type. The impact force shall be permitted to be limited to the crushing strength of the ship or barge.

The mass and stiffness to be used for debris impact in Sections 5.4.5.1.2 and 5.4.5.1.3 shall not be less than the minimum values provided in Table 5.4-4.

Table 5.4-4. Minimum Debris Properties.

Debris Type	Minimum debris weight (W_{debris})	Minimum elastic debris stiffness (k_e)
Wood Log/Pole	1,000 lb (4.448 kN)	4,200,000 lb/ft (61,300 kN/m)
Passenger Vehicle	2,400 lb (12.455 kN)	72,000 lb/ft (1,051 kN/m)
Small Vessels	2,500 lb (11.121 kN)	360,000 lb/ft (5,254 kN/m)
20 ft Shipping Container	5,000 lb (22.241 kN)	2,940,000 lb/ft (42,900 kN/m)

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40 ft Shipping Container	8,400 lb (37.365 kN)	2,040,000 lb/ft (29,800 kN/m)
Ships/Barges	Established based on local conditions	

Where debris impacts from shipping containers, ships or barges exceed the capacity of the structural element, it shall be permitted to accommodate the impact through the provisions in Section 5.4.5.4. The provisions of Section 5.4.5.4 may be used for all debris impact types on individual piles.

5.4.5.3 Extraordinary Debris Impact

Extraordinary debris impact loading shall be based on the stiffness and weight in accordance with Section 5.3.9.1.1. The debris impact force shall be applied for the worst-case location on the impacted element from a depth of the eroded grade up to the design stillwater flood depth plus the maximum freeboard of the vessel. The load from the extraordinary debris shall be calculated from Equation (5.4-20) or alternative analysis of Section 5.4.5.1.3.

EXCEPTION: Either as the primary approach, or where the impact loads from extraordinary debris exceed the capacity of any structural element subject to impact, it shall be permitted to accommodate the impact through the progressive collapse provisions of Section 5.4.5.4.

5.4.5.4 Debris Impact Load Redistribution

Where permitted by Section 5.4.5.2 or 5.4.5.3, alternate load path progressive collapse provisions in accordance with the recognized literature shall be applied to perimeter columns, piles, and beams from ground level to the Design Stillwater Flood Depth plus the height of the deck of the vessel from the waterline where applicable.

5.5 FLOOD LOAD CASES

The flood load (F_a) used in the Chapter 2 load combinations shall include the following flood load cases in the applicable directions:

For coastal flooding:

1. Combination of hydrostatic loads including buoyancy (5.4.2), hydrodynamic loads (5.4.3) and debris impact loads (5.4.5)
2. Combination of hydrostatic loads including buoyancy (5.4.2), hydrodynamic loads (5.4.3) and wave loads (5.4.4)

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For riverine flooding:

1. Combination of hydrostatic loads including buoyancy (5.4.2), hydrodynamic loads (5.4.3) and debris impact loads (5.4.5)

5.5.1 Stability Against Uplift.

Structures shall be designed to resist flotation due to buoyancy forces as defined in Section 5.4.2.1. Uplift resistance shall be provided by satisfying Equation (5.5-1) with load factors as shown. This stability load combination is in addition to those in Chapter 2.

$$0.9D_{SW} + R_B + F_B + 0.6W_{uplift} \geq 0 \qquad (5.5\text{-}1)$$

where

D_{SW} = Self-weight of the structure or portion of structure being evaluated inclusive of permanent fixed elements and equipment, in lb (kN),

R_B = Allowable uplift resisting capacity of structural foundation elements and/or other conditions resisting uplift, in lb (kN),

F_B = Uplift force caused by buoyancy in lb (kN), always taken as less than zero, and

W_{uplift} = Maximum total vertical uplift wind load on the structure as defined in this standard, in lb (kN). Wind load shall not be used to counteract buoyancy and is always taken less than zero.

5.5.2 Stability Against Sliding

Sliding resistance shall be provided by satisfying Equation (5.5-2) with load factors as shown. This stability load combination is in addition to those in Chapter 2:

$$\mu(0.9D_{SW} + F_B + 0.6W_{uplift}) + H_p + R_p - H_a - F_{lateral} - 0.6W_{lateral} \geq 0 \qquad (5.5\text{-}2)$$

where

μ = Coefficient of sliding friction at slip plane being considered between structure on shallow foundations and subgrade,

D_{SW} = Self-weight of the structure or portion of structure being evaluated inclusive of permanent fixed elements and equipment, in lb (kN),

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F_B = Uplift force caused by buoyancy in lb (kN) always taken as less than zero,

W_{uplift} = Maximum total vertical uplift wind load on the structure as defined in this standard, in lb (kN). Wind load shall not be used to counteract buoyancy and is always taken less than zero,

H_p = Resultant force from passive lateral earth pressures, in lb (kN),

R_p = Allowable lateral resisting capacity of deep foundations, external structural foundation elements and/or other conditions resisting sliding, in lb (kN),

H_a = Resultant force from active lateral earth pressures, in lb (kN),

$W_{lateral}$ = Maximum total lateral wind load on the structure as defined in this standard, in lb (kN), and

$F_{lateral}$ = Maximum lateral component of the flood load, Fa, as determined in Section 5.5, in lb (kN).

Global sliding shall be evaluated for whichever directions of wind load and flood loads result in the more severe loading case. The effects of scour on the depth of soil contributing to lateral earth pressures shall be included in this evaluation.

5.6 CONSENSUS STANDARDS AND OTHER AFFILIATED CRITERIA

This section lists the consensus standards and other affiliated criteria that shall be considered part of this standard to the extent referenced in this chapter.

ASCE/SEI 24 *Flood resistant design and construction*, ASCE, 2014.

Cited in: Section 5.3.9, 5.3.10

COMMENTARY

Chapter C1: General

C1.3.1.3 Performance-Based Procedures

….. For seismic design, the provisions of the ASCE 41 standard and of the Tall Buildings Imitative, Guidelines for Performance-Based Seismic Design of Tall Buildings (PEER 2010) were either calibrated by structural performance level or were demonstrated in comparison with prescriptive design methods to provide reliabilities equal or better than Table 1.3-2.

In previous editions of this standard (2022 and previous), structures within the 100-year Coastal A zones and V zones were subject to a load factor of 2.0 that was based on a beta value of 2.5 (Mehta et al. 1998) rather than 3.0. A reliability analysis by the Flood Load Subcommittee for ASCE 7-22 Supplement 2 confirmed that using the 100-year design flood produced a beta of less than 2.5, which is below the target reliabilities outlined in this standard. As a result, the basis of

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design was changed to a risk-based approach using mean recurrence intervals associated with different risk categories of structure to achieve the target reliability.

Chapter C2: Combinations of Loads

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C2.3.2 Load Combinations Including Flood Load

In ASCE 7-22 Supplement 2, the flood load requirements of Chapter 5 are updated from a 100-year hazard basis, which was developed for the FEMA National Flood Insurance Program (NFIP), to a risk category (RC) targeted return period basis (100-year, 500-year, 750-year, and 1,000-year flood for Risk Categories I, II, III, and IV, respectively). At the time of the change, longer return period flood maps (specifically 750-year and 1,000-year maps) are not available for all communities. Therefore, a scale factor for the flood loading is provided in Section 5.3, which approximates the longer return period floods from the 100-year mapped flood. These scale factors were established based on data from simulated storms impacting the Gulf and Atlantic coasts based on USACE mapping projects (Refer to Section C5.3). This change in approach, along with revised loading equations, is a significant departure from previous versions of ASCE 7. With this change, the load factor of 2.0 previously used for coastal flood hazard areas, with significant uncertainty relative to the base flood, is no longer necessary. Based on the increased return period and the inherent conservatism in some of the equations of Chapter 5, a load factor of 1.0 is appropriate for LRFD design. Similar to other hazards, the ASD load factor is taken as 0.7 (1/1.5 rounded to one significant digit) of the LRFD load factor. The load factor of 1.0 r was justified with a reliability analysis. The reliability analysis incorporated the revised return period requirements and loading criteria in Chapter 5 using hazard curve data from the USACE studies. The analysis considered a column structure and a wall within a structure located at several elevations above the datum. The target reliabilities were taken from Chapter 1, consistent with other environmental hazards such as wind and seismic. The uncertainty in the flood load design is based on several variables, including design stillwater flood elevation, velocity, and wave height. The reliability analysis accounts for these variables.

While flooding can occur in storms that produce tornadoes the spatiotemporal correlation between tornadoes and flooding is much less than that between hurricane winds and flooding. Therefore, the load combinations from Section 2.3.2 maximizing flood loads do not include arbitrary point-in-time tornado loads.

The reliability analysis performed for ASCE 7-22 Supplement 2 did not incorporate wind loading or below grade soil pressures. Therefore, the load factors for these elements remain unchanged. The 1.6 load factor specified for H loads (below-grade soil) in Section 2.3.1 is applied for groundwater induced lateral and uplift pressures for structural element design. Section 2.3.7

provides an alternative method for loads from water in soil. It should be noted that flood water and groundwater are not necessarily connected. This relationship depends on the subsurface soil characteristics. Stability for global uplift does not use the 1.6 load factor and should be checked per Section 5.5.1.

C2.4.2 Load Combinations Including Flood Load

See Section C2.3.2. The multiplier on F_a aligns allowable stress design for flood load with strength design.

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Chapter C5: Flood Loads

C5.1 GENERAL

This chapter presents information for the design of buildings and other structures in areas prone to flooding. Design professionals should be aware that there are important differences between flood characteristics, flood loads, and flood effects in riverine and coastal areas (e.g., the potential for wave effects is much greater in coastal areas, the depth and duration of flooding can be much greater in riverine areas, the direction of flow in riverine areas tends to be more predictable, and the nature and amount of flood-borne debris varies between riverine and coastal areas).

This chapter is applicable to the vertical and lateral force resisting systems of buildings and other structures, and to the elements of a dry flood-proofed building such as cladding, opening barriers, and other associated components forming the flood-resistant perimeter. In addition, the phrase “other structures” is meant to cover building-like structures designed to resist flood-related loads. This standard does not cover levees, dikes, piers, wharves, roads, or bridges.

Much of the research regarding flood loads is based on the analysis and testing of individual components such as columns or walls subjected to stillwater, current, wave impact, or debris impact. As many buildings are elevated on piles, columns, or shear walls, the component testing is directly applicable to buildings and other structures within the flood plain. For complicated geometries and structures with enclosures below the design flood elevation, the designer should review recognized literature and consider whether project specific studies are warranted.

Flood resistant perimeters typically have openings that are sealed by deployed barriers prior to a storm event. These barriers are not considered temporary elements even if not permanently attached to the flood-resistant perimeter. All components of a perimeter flood-resisting system,

including deployed opening barriers, are considered as associated components of a building and are subject to the applicable loads as described in this chapter.

Much of the impetus for flood-resistant design has come about from the federal government sponsored initiatives of flood-damage mitigation and flood insurance, both through the work of the US Army Corps of Engineers (USACE) and the National Flood Insurance Program (NFIP). The NFIP is based on an agreement between the federal government and participating communities that have been identified as being flood prone. The Federal Emergency Management Agency (FEMA), through the Federal Insurance and Mitigation Administration (FIMA), makes flood insurance available to the residents of communities provided that the community adopts and enforces adequate floodplain management regulations that meet the minimum requirements. Included in the NFIP requirements, found under Title 44 of the US Code of Federal Regulations (FEMA 2020), are minimum building design and construction standards for buildings and other structures located in special flood hazard areas (SFHAs).

Special flood hazard areas are those identified by FEMA as being subject to inundation during the 100-year flood. SFHAs are shown on flood insurance rate maps (FIRMs), which are produced for flood-prone communities. SFHAs are identified on FIRMs as Zones A, A1-30, AE, AR, AO, and AH, and in coastal high hazard areas as V1-30, V, and VE. The SFHA is the area in which communities must enforce NFIP-compliant, flood damage-resistant design and construction practices.

Answers to specific questions on flood-resistant design and construction practices may be directed to the mitigation division of each of FEMA's regional offices. FEMA has regional offices that are available to assist design professionals.

Buildings and other structures constructed in areas prone to flooding may additionally be subject to the requirements of ASCE 24 Flood Resistant Design and Construction, where required by the Authority Having Jurisdiction. ASCE 24 is referenced by the International Building Code. Minimum elevation requirements for structures set by ASCE 24 may differ from the elevations of loads in this chapter and do not preclude the occurrence of flood loads specified by this chapter. Designers may choose to elevate a structure above the elevations mandated in ASCE 24 to reduce the loads applied to the structure.

Buildings and other structures constructed in areas prone to flooding are additionally subject to the flood extent and elevation requirements of the Authority Having Jurisdiction.

C5.2 DEFINITIONS AND SYMBOLS

In ASCE 7-22 Supplement 2, higher return periods for flood design loads were introduced that exceed the base flood in elevation and spatial extent. The increase in spatial extent is limited to

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the addition of mapped Shaded X zones (the 500-year floodplain) for Risk Categories II, III, and IV structures.

Many communities have elected to regulate to a flood standard higher than the minimum requirements of the NFIP. Those communities may do so in a number of ways. For example, a community may require new construction to be elevated a specific vertical distance above the base flood elevation (this is referred to as “freeboard”); a community may select a lower frequency flood as its regulatory flood; or a community may conduct hydrologic and hydraulic studies, upon which flood hazard maps are based, in a manner different from the Flood Insurance Study prepared by the NFIP (e.g., the community may complete flood hazard studies based upon development conditions at build-out, rather than following the NFIP procedure, which uses conditions in existence at the time the studies are completed; the community may include watersheds smaller than 1 mi^2 (2.6 km^2) in size in its analysis, rather than following the NFIP procedure, which neglects watersheds smaller than 1 mi^2 (2.6 km^2). Flood Insurance Studies (FIS) are official reports prepared by FEMA and typically correspond to several FIRMs within a geographic region and provide supporting technical data. Flood Insurance Studies are one example of a flood hazard study that may be adopted by a community. Flood Insurance Studies typically contain flood elevation data in

C5.3 DESIGN REQUIREMENTS

ASCE’s comprehensive flood hazard requirements are split between two standards: ASCE 7 and ASCE 24, both of which are referenced by the International Building Code. While the provisions of ASCE 7 focus solely on flood loads and where flood loads are to be applied, Sections 5.3.9 and 5.3.10 reference the requirements of ASCE 24 for the application of several ASCE 7 provisions. In addition, it is helpful to designers to clarify the role of ASCE 24 and how the two documents are related, as they are on different update cycles.

ASCE 24 references ASCE 7 for loads on structures within Flood Hazard Areas. ASCE 24 provides minimum requirements for flood resistant design and construction of structures that are subject to building code requirements and that are located, in whole or in part, in Flood Hazard Areas as defined by the Authority Having Jurisdiction. ASCE 24 has requirements that vary depending on flood zone, and that govern the design and construction of foundations, elevation of the lowest floor, elevation of utility equipment, enclosures below the Design Flood Elevation (DFE), use of flood-damage-resistant materials, wet and dry floodproofing, and other miscellaneous items. ASCE 24 is adopted by reference in the International Building Code. A summary of the ASCE 24 requirements is contained on the section of FEMA’s website for flood building codes; https://www.fema.gov/sites/default/files/2020-07/asce24-14_highlights_jan2015.pdf.

Revisions to Chapter 5 in ASCE 7-22, Supplement 2 provide a risk-informed basis for flood loads with MRIs that are higher than those specified by the NFIP and provide a basis for

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determining flood loads for structures in areas for which the NFIP has no flood maps or requirements.

C5.3.1 Flood Hazard Area

Beginning with ASCE 7-22 Supplement 2, the Flood Hazard Area was increased from the 100-year flood plain (the Special Flood Hazard Area) to the 500-year flood plain (the SFHA *and* the shaded X-zone) for Risk Categories II, III, and IV structures to improve the performance of these structures subjected to flood events and to meet the target reliabilities of the Standard. In addition, the flood hazard Mean Recurrence Interval (MRI) was also redefined per risk category as part of the effort to transform overall reliability of the chapter. The MRI embedded in the extent of the Flood Hazard *Area* is not the same as the MRI in used to find the Design Stillwater Flood Depth in Section 5.3.3 for the hazard. A 100-year MRI flood event has a 39% probability of being equaled or exceeded over a 50-year service period, and a 500-year MRI flood event has a 10% probability of being equaled or exceeded over a 50-year service period. The increase in flood load requirements will improve the performance of structures, and better align flood hazards with the approach to wind and other hazards. The approach of ASCE 7-22 Supplement 2 better accounts for the hazard variations by applying an increased flood depth, which applies loads distributed over a larger height, instead of increasing the force over the 100-year flood depth on the structure. It is recognized that the Risk Categories III and IV structures with MRI floods that exceed the 500-year requirement correspond to a flood zone that exceeds the mapped 500-year floodplain, which is the limit of ASCE 7-22 Supplement 2. This results in structures outside of the mapped 500-year floodplain not having design requirements where they would see flood waters in larger return period events. This was deemed acceptable due to the relatively small depths seen beyond the 500-year floodplain. The increase in design MRI for flood events provides a hazard level that will provide the target reliability when combined with the load combination factors in Chapter 2.

C5.3.2 Design Loads

Wind loads, rain loads, and flood loads may act simultaneously at coastlines, particularly during hurricanes and coastal storms. This may also be true during severe storms at the shorelines of large lakes and during riverine flooding of long duration. This chapter, along with Chapter 2, provides updated guidance on how to consider and combine various types of flood loads.

For both the Flood Hazard Area and the Design Stillwater Flood Depth, which is defined in the following section, an Authority Having Jurisdiction may have adopted flood criteria that are more restrictive than that presented in ASCE 7-22 Supplement 2.

C5.3.3 Design Stillwater Flood Depth

In implementing the MRI flood requirements in Table 5.3-1, two key concepts are acknowledged. First, specific design flood requirements of the Authority Having Jurisdiction

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govern and may be above the mapped 100-year stillwater elevation. Second, design flood requirements in this standard may exceed those currently defined in ASCE 24 or by an Authority Having Jurisdiction relative to lowest floor elevation. Floor elevation requirements are closely related to insurance and local zoning programs and are sometimes highly contested. A design stillwater flood depth in excess of a dry floodproofed design flood elevation might narrowly be thought of as excessive because the added design depth would imply water inundation defeating the economic loss mitigation purpose of the dry floodproofed perimeter. However, an appropriately reliable structural design also prevents structural failure, or washing away of the structural system itself, which then becomes debris for other buildings.

The design stillwater flood depth is a key parameter in establishing the flood loads; it is based on the flood elevation for the specified MRI, also accounting for the erosion of the ground surface and sea level rise.

In ASCE 7-22 Supplement 2, loads in Chapter 5 are based on the stillwater elevation. In prior editions, flood loads also were based on stillwater elevation, but the chapter referenced a DFE in some load calculations. ASCE 7-22 Supplement 2 drops the reference to the DFE.

If needed for comparison purposes, the ASCE 7-22 Supplement 2 coastal DFE can be determined in accordance with Equation (C5.3-1):

$$DFE = d_f + G_e + 0.7H_{design} \quad \text{(C5.3-1)}$$

where

H_{design} = Design wave height in ft (m) as calculated in Section 5.3.7.1,

G_e = Elevation of grade at the building or other structure inclusive of effects of erosion in ft (m), per Section 5.3.5, and

d_f = Design stillwater flood depth, in ft (m), per Section 5.3.3.

The ASCE 7-22 Supplement 2 riverine DFE is the same as the Design Stillwater Flood Elevation. The DFE calculated above is not the same DFE that is used for NFIP, ASCE 24, or other model building code purposes. Each DFE should be calculated separately per the applicable Standard for its intended purpose.

C5.3.3.1 Stillwater Elevation Determination When MRI Data Not Available

For most populated areas, flood maps are available for 100-year and more recently 500-year MRI. The design flood for Risk Categories II, III, and IV structures was set at higher return periods for closer alignment with other hazards within ASCE 7. To avoid requiring a site-

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specific study for each building, a method of "scaling up" the flood to larger return periods has been provided in Table 5.3-1. These factors were generated based on compiling data from flood studies with thousands of individual data points. Scale factors for all MRI values apply to the 100-year stillwater elevation and do not include the effects of relative sea level change.

The following studies were used in the development of Table 5.3-1 and discussion in C5.3.3: Cialone et al. (2015), Nadal-Caraballo et al. (2015), and Melby et al. (2020).

The term *coastal sites* refers to the source of flooding, not the site location. For example, if the hazard being considered for an inland building is hurricane storm surge from a source fed by an ocean or the Gulf of Mexico, this is considered coastal flooding and the appropriate scale factors are to be used. For coastal sites, the C_{MRI} factor was developed enveloping the data from four studies from the US Army Corps of Engineers (USACE). The study regions were North Atlantic (Virginia – Maine), Texas, Louisiana, South Florida to North Carolina and Alabama/Florida Panhandle. The following figures (C5.3-1, C5.3-2) show examples of these studies with the mean, and plus and minus standard deviation factors to scale 100-year flood elevations to longer return periods.

To establish scale factors for design, the studies were grouped into two geographic regions (Gulf Coast and Atlantic Coast). To do this, the scaling curves for each study were enveloped for the region. It is recognized by enveloping the different geographic regions that conservatism is then built into the design flood depths. In addition, the scale factors are rounded up to the nearest 0.05 value. This can be seen in Figures C5.3-3 and C5.3-4 with the compiled mean scale factors. These skewed scale factors are one reason why reductions below ASCE 7 values are allowed for site-specific studies. ASCE 7 requires the coastal scale factors apply to all coastal conditions even though they were developed based on the hazard curves for the East Coast and Gulf Coast. The hazard curves for the West Coast (i.e., Washington, Oregon, California) are significantly flatter than the values listed in Table 5.3-1 thus the values are conservative.

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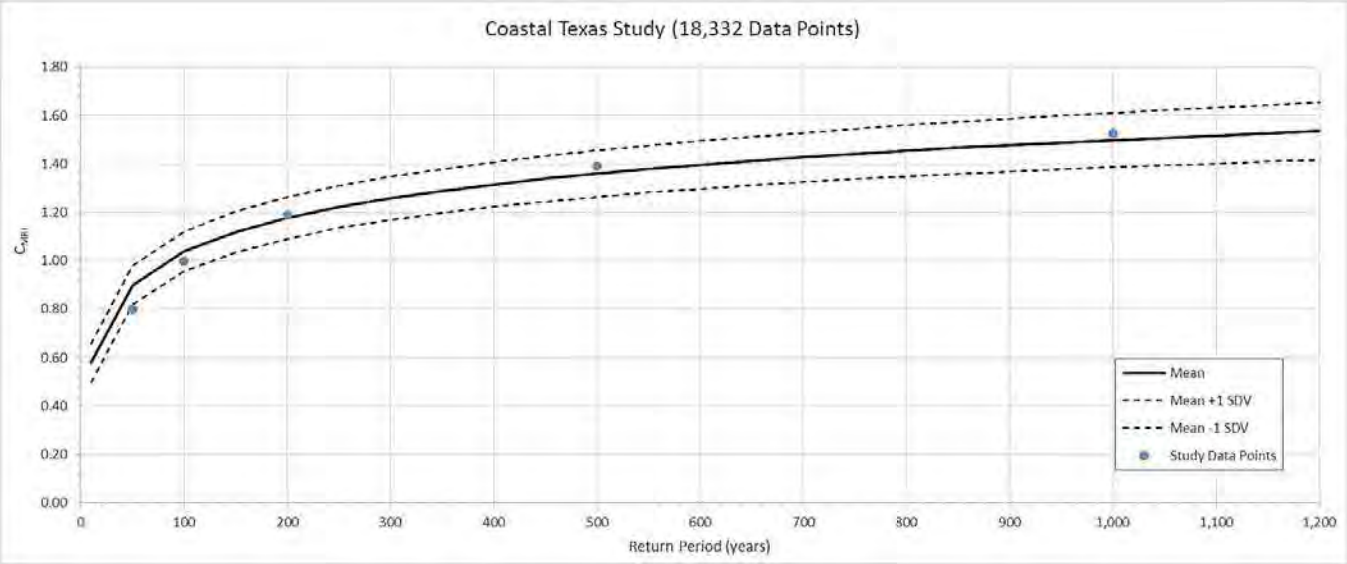


Figure C5.3-1. C_{MRI} Curve for Texas Based on USACE Data.

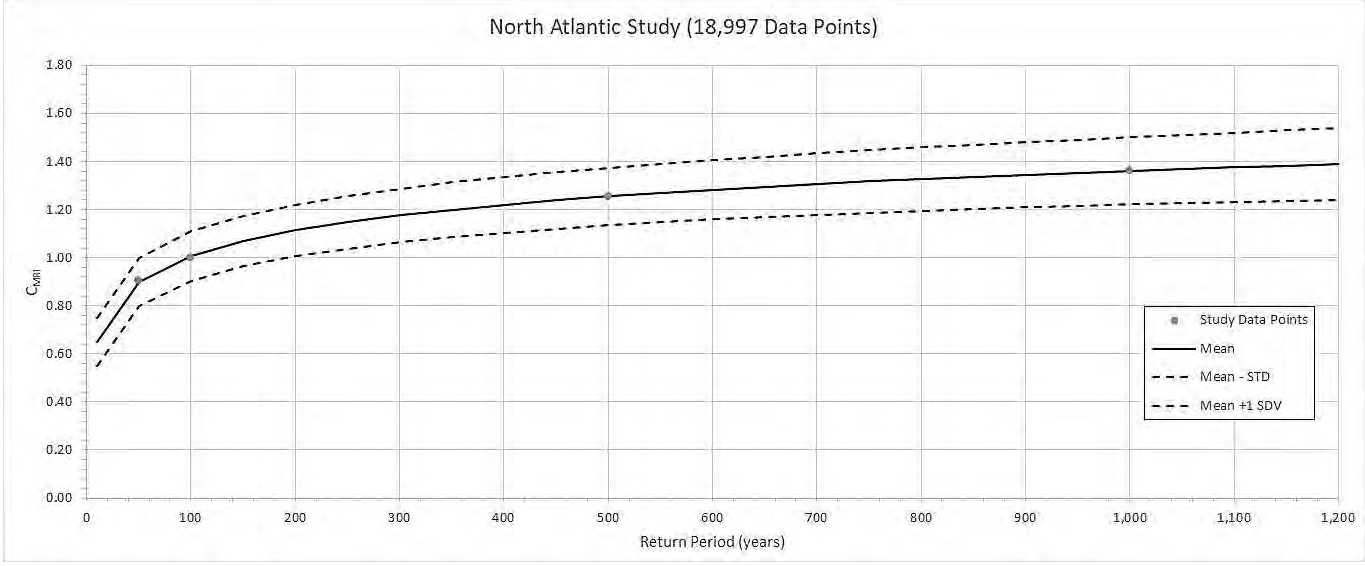


Figure C5.3-2. C_{MRI} Curve for North Atlantic Based on USACE Data.

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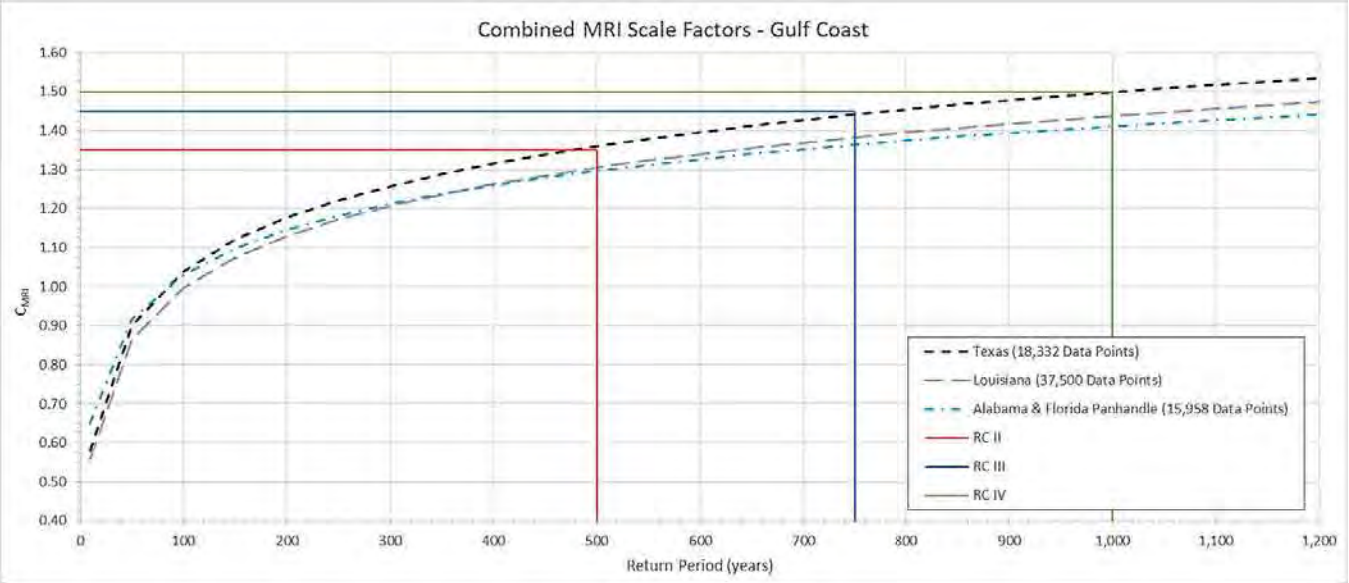


Figure C5.3-3. Combined Coastal Scale Factors for the Gulf of Mexico Coastal Region.

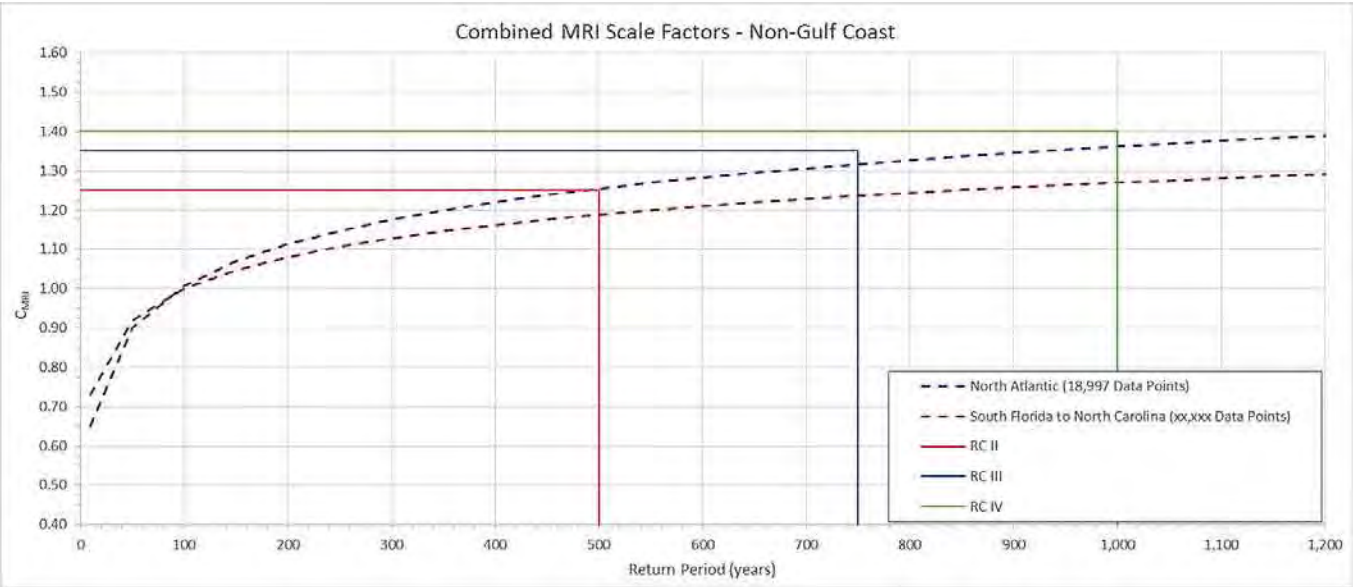


Figure C5.3-4. Combined Coastal Scale Factors for Non-Gulf of Mexico Coastal Regions.

A similar effort was done for the scale factors for the US Great Lakes. Data points from transects of USACE flood studies were taken around each lake to produce scale factor curves for each lake. Figure C5.3-5 shows the scale factor curves for each lake with the selected scale factor for each risk category.

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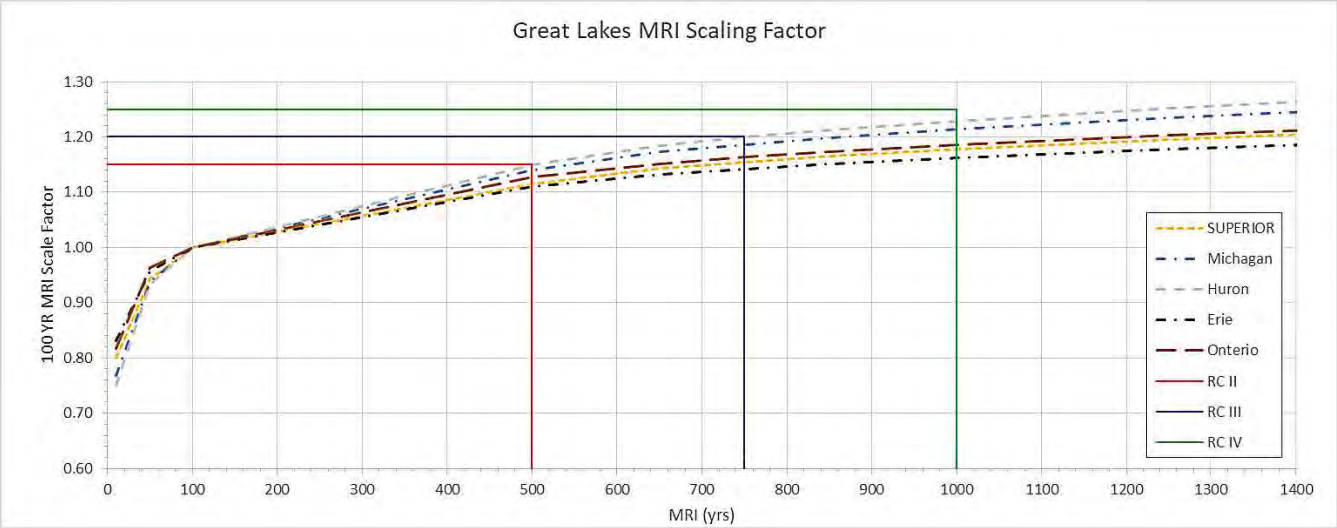


Figure C5.3-5. Scale Factor Curves for the Five US Great Lakes.

The riverine scale factors were established based on flood studies from rivers in the Midwest. Data from an Iowa floodplain study (Gilles et al.) was used to validate the theoretical scale factors. The riverine sites scale factors from location to location were significant as can be seen in Figure C5.3-6. In addition, site datum elevations were not available, so the 1-year return period had to be extrapolated; this results in the scale factors appearing larger than if the actual datum values were used.

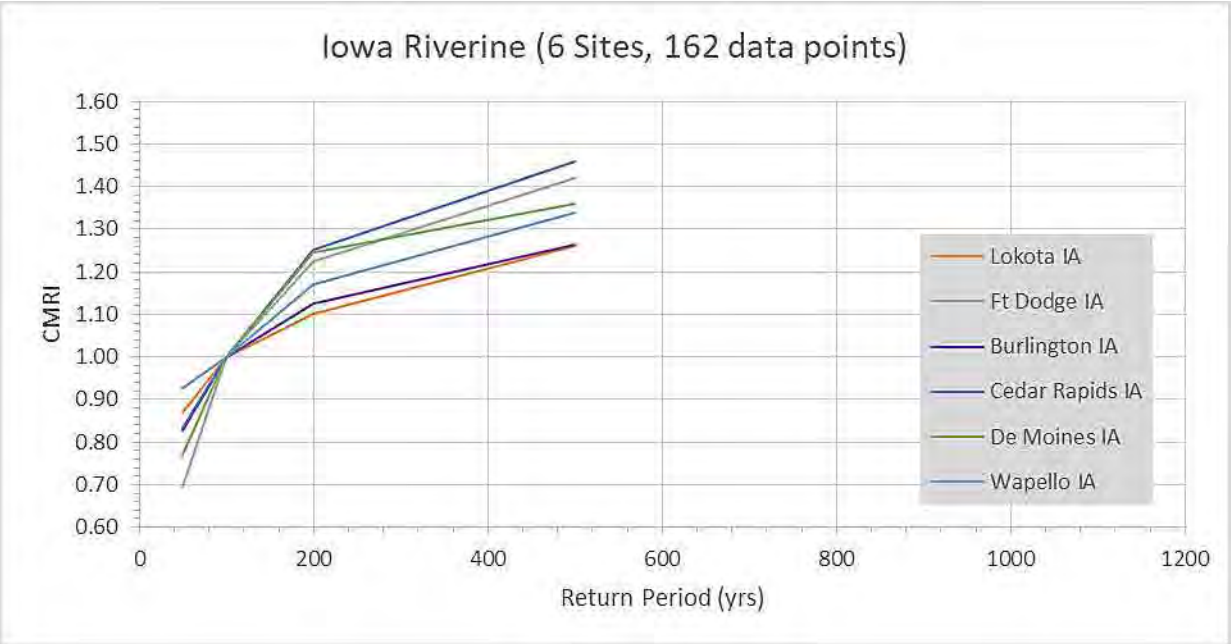


Figure C5.3-6. Scale Factor Curves for the Six Sites in Iowa.

Similar to the coastal studies, data across all sites were aggregated and a single scale factor was set for each risk category. Figure C5.3-7 summarizes the data with the scale factors shown. While not a comprehensive data set for all riverine sites, the data from six sites in Iowa provide validation of the scale factors selected.

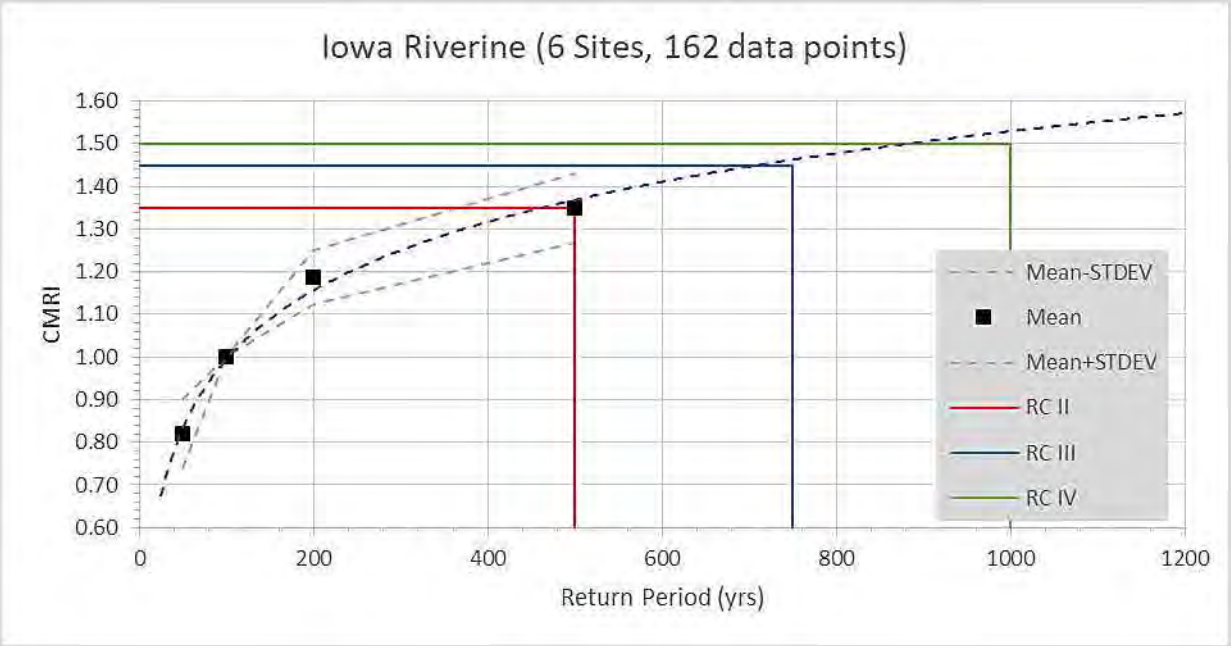


Figure C5.3-7. Summary of the Scale Factors on Iowa Riverine Sites.

The value Z_{datum} in Equation (5.3-2) is to adjust for the base water level. If Z_{datum} were not accounted for, then the elevation of the river or lake would be amplified. For most lakes, a datum is a given value for that lake and can be used for scaling. However, this is often not available for rivers where the base datum is almost never known from location to location. To simplify the analysis, the annual high-water elevation can be used to determine the flood elevations. The annual high-water level is slightly larger than the river datum, so it generates a slightly conservative flood elevation. The reference datum for each US Great Lake is shown in Table C5.3-1.

Table C5.3-1. Great Lakes Chart Datum.

Lake	Datum – NAVD88 (ft)
Superior	601.0
Michigan	578.1

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Huron	578.1
Erie	570.1
Ontario	244.0

ASCE 7-22 Supplement 2 continues to recognize the FEMA Flood Insurance Rate Maps (FIRMs) as the standard for defining the Base Flood Elevation (BFE) because of their widespread coverage and usage. However, one limitation of the maps is that they do not account for sea level rise, increased precipitation, or other conditions such as long-term erosion. In addition, a site that is in the X-Zone today could be in an A-Zone in the future due to the impact of changes in the local climate between updates to ASCE 7 or to FEMA FIRMs. For this reason, structural flood load requirements have been added for areas identified in the 500-year flood zone (0.2% chance of annual exceedance) and related to the adjacent BFE.

C5.3.4 Effects of Relative Sea Level Change

Relative sea level change combines changes in sea level with the effects of local subsidence (which may be caused by extraction of underground resources, drought, and/or soil decomposition) and post-glacial rebound (caused by relaxing of land masses due to melting of glaciers at the end of the last glacial period). Several climate scenarios have been developed by the US Army Corps of Engineers (USACE), National Oceanic and Atmospheric Administration (NOAA), US Global Change Research Program, and the Intergovernmental Panel on Climate Change (IPCC), among others. In addition, many state and local climate change reports exist and may be used as guidance.

Several assumptions are needed to forecast relative sea level rise through a project's service life; thus, significant uncertainty exists in its prediction. The lower bound of future relative sea level change is typically taken as a straight-line projection of historic/recent relative sea level change. This represents the minimum required value to be used in design as defined in ASCE 7-22 Supplement 2. In lieu of more specific local or client guidance, the USACE Sea Level Change Curve Calculator (https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html) may be used to estimate future relative sea level change. The tool lists the historical annual rate of sea level rise or fall, and this should be projected over the anticipated lifespan of the structure. Where this historic rate of change is negative, relative sea level change is required to be taken as zero in the calculation of flood loads and conditions. Another reference that can be considered is the ASCE Manual on Engineering Practice No. 140, *Engineering Practice, Climate-Resilient Infrastructure: Adaptive Design and Risk Management* (2018).

C5.3.5 Erosion

The term *erosion* indicates a lowering of the ground surface in response to a flood event, or in response to the gradual recession of a shoreline primarily due to sediment transport. The term

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scour, as used elsewhere in this chapter, indicates a localized lowering of the ground surface during a flood, due to the interaction of currents and/or waves with a structural element. Erosion can affect the stability of foundations and increase the local flood depth and flood loads acting on buildings and other structures. For these reasons, erosion should be considered during load calculations and the design process. Design professionals often remove or mitigate effects of erosion by increasing the depth of foundation embedment, providing armoring or siting buildings away from receding shorelines (building setbacks).

Causes of erosion include storm surge, wind, relative sea level change, dredging, vegetation clearing, river damming, and land reclamation. Erosion may result in permanent or frequent inundation, more frequent flood damage, disconnection of road access networks, and increases or shifting in flood zones. Resources available to estimate current and future erosion rates include state coastal programs, USGS or State Geological Survey Agencies, USACE, and universities. Consult the Authority Having Jurisdiction for any adopted erosion projections.

Erosion can occur over different time intervals whether it be years, months, or weeks due to different modes of sediment transport. Erosion can also be episodic, occurring during a single flood event occurring over days or hours.

C5.3.6 Flood Velocity

Accurate estimates of flow velocities during flood conditions are very difficult to make, both in riverine and coastal flood events. Unlike high water marks that are often recorded during flood events, there are relatively few reliable observations of flood velocity. Potential sources of information regarding velocities of floodwaters include local, state, and federal government agencies and consulting engineers specializing in coastal engineering, stream hydrology, or hydraulics.

Figure C5.3-8 shows an example flood hazard study of the overland flow velocity due to hurricane surge at Galveston, Texas. The figure relates the estimated velocity to the local flow depth via the equation $V = \sqrt{(gh)}$ where h is the local flow depth in this figure. Figure C5.3-8 shows that this equation used in ASCE 7-16 is overly conservative (solid line) and that the use of a reduction coefficient $C_V = 0.5$ (dashed line) and upper limit (V_{max} = 10 ft/s, 3.05 m/s) is more reasonable.

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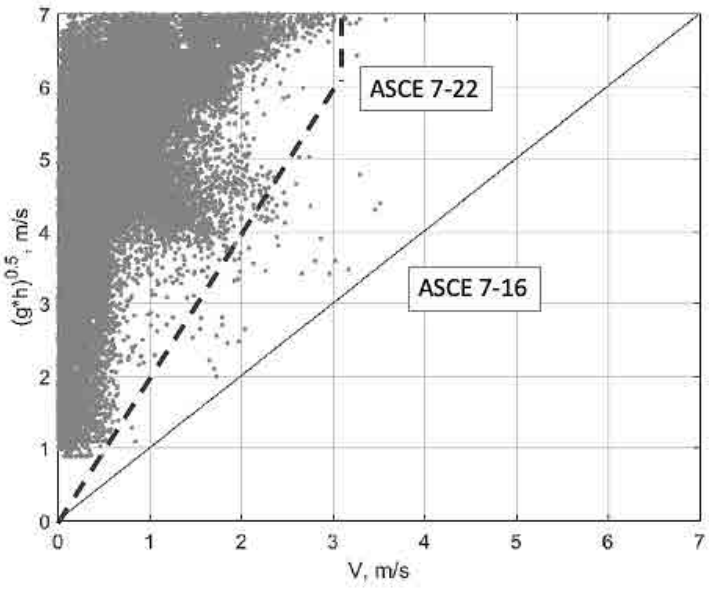


Figure C5.3-8. Example USACE Comprehensive Coastal Study Using Numerical Simulation of Overland Flow Velocity due to Hurricane Surge at Galveston, Texas.

The magnitude and direction of the flow can vary in time at a given location, and the velocity can vary spatially at a given instance in time. The maximum velocity often does not occur at the same time as the maximum flood depth. The velocity can vary with depth, with larger velocity at the mean water level and smaller velocity near grade level.

The velocity can vary with depth at a given location. Most numerical reports provide the flow as a depth-averaged velocity.

The magnitude and direction of the flow can be influenced by the presence of large buildings, such as enclosed structures of concrete, masonry, or structural steel construction located in close proximity to the site, that can accelerate the flow between buildings. Some buildings or other obstacles such as coastal forests can provide shielding to reduce the flow speed. The magnitude and direction of the flow can be affected by local changes in topography and changes in surface roughness such as pavement and vegetation.

During a coastal flood event, the flow velocity can approach a structure from different directions over the course of the event.

C5.3.7 Wave Effects

C5.3.7.1 Wave Height

Wave load and scour calculations in ASCE 7-16 depended on the initial computation of the wave height. The wave height computations in ASCE 7-16 resulted from the assumptions that the waves are depth-limited and that waves propagating into shallow water break when the wave height equals 78% of the local still water depth. Designers should be aware that wave heights at a particular site can be less than depth-limited values in some cases (e.g., when the wind speed, wind duration, or fetch is insufficient to

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generate wave large enough to be limited in size by water depth, or when nearby objects dissipate wave energy and reduce wave heights).

Because the assumption of depth-limited waves may be overly conservative in some cases, ASCE 7-22 Supplement 2 allows for the computation of scour depth and wave loads based on nonbreaking waves of a wave height lower than the depth-limited wave height. Figure C5.3-9 illustrates a procedure to utilize information that may yield a wave height lower than the conservative estimate of a depth-limited breaking wave at the site and a procedure to determine if the computed wave height at a site is a breaking or nonbreaking wave. The figure is divided into three branches. To start, the designer must determine if the wave height information is available at the site from a flood hazard study. If the answer is yes, then the designer proceeds to Branch 1. If no, then the designer must determine if the wave height information is available at the shoreline. If yes, then the designer proceeds to Branch 2. If no, then the designer proceeds to Branch 3.

In Branch 1, the designer determines whether the wave height at the site is provided in terms of the controlling wave height, H_c. If no, the designer converts the given wave height to the controlling wave height using appropriate wave statistics. For example, the significant wave height can be converted to the controlling wave height through the relationship, $H_c = 1.6\ H_s$, under the assumption of a Rayleigh distribution of wave heights. Next, the designer scales H_c for the desired recurrence interval corresponding to the given risk category of the structure by C_{HC} from Table 5.3-3. Finally, the designer checks whether the computed $C_{HC}H_c$ exceeds the depth-limited breaking wave height H_b. If the computed $C_{HC}H_c$ exceeds H_b, then the wave is considered a breaking wave and the design wave is set at $H_{design} = H_b$. If H_c is less then H_b, then the wave is considered a nonbreaking wave and the design wave height is set at $H_{design} = C_{HC}H_c$.

In Branch 2, the designer determines whether the wave height at the shoreline is provided in terms of the controlling wave height, H_c. The steps are the same as in Branch 1 but applied to the wave heights at the shoreline. Because the wave height is at the shoreline and not at the site, Branch 2 requires an additional step to take the wave height from the shoreline to the site, with potentially smaller wave heights at the site.

There are four methods to calculate the wave height at the site. In Method 1, the designer can use a one-dimensional transect model such as WHAFIS that is used in FEMA Flood Insurance Studies. WHAFIS is based on the 1977 National Academy of Science (NAS) study titled "Methodology for Calculating Wave Action Effects Associated with Storm Surges." Using the methods presented in the NAS study, a designer could use Table C5.3-2 to transform the wave height from the shoreline to an inland site. Table C5.3-2 provides example wave height factors. The wave height factors in Table C5.3-2 uses the experimental results and NAS procedure, and accounts for some conservatism related to incident wave direction and building array geometry (staggering of buildings within the array).

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Table C5.3-2. Number of Shielding Rows of Structures and Wave Height Factor.

NUMBER OF SHIELDING ROWS*	WAVE HEIGHT FACTOR
0 or 1	1.0
2 or 3	0.7
4 or 5	0.5
6 or more	0.3

* Requirements to be considered a shielding row:

1. A seaward shielding structure must be robust enough to remain intact during the design storm event. A building whose façade fails while the primary frame does not, is not considered a shielding structure. Buildings or barriers constructed of wood, light gage steel, aluminum, or any similarly performing material, shall be considered nonshielding unless proven otherwise by an engineering analysis.

2. Only rows less than 70% open distance between buildings relative to total distance measured parallel to shore can be considered as a shielding row.

In Method 2, the designer can use H_c at the shoreline as H_c at the site as a conservative approach unless there is a large fetch between the shoreline and the site. In Method 3, the designer can use a more advanced numerical procedure. In Method 4, the designer can use a laboratory study. Finally, the designer checks whether the computed H_{design} at the site exceeds the depth-limited breaking wave height H_b similar to the steps for Branch 1.

In Branch 3, the designer does not have access to or does not have the means to use the wave height information at the site or at the shoreline. The designer assumes a depth-limited breaking waves H_b at the site. This wave height is used as the basis for design, $H_{design} = H_b$, and is consistent with the ASCE 7-16 standard. Branch 3, consistent with ASCE 7-16, is the most conservative approach and is permitted to be used.

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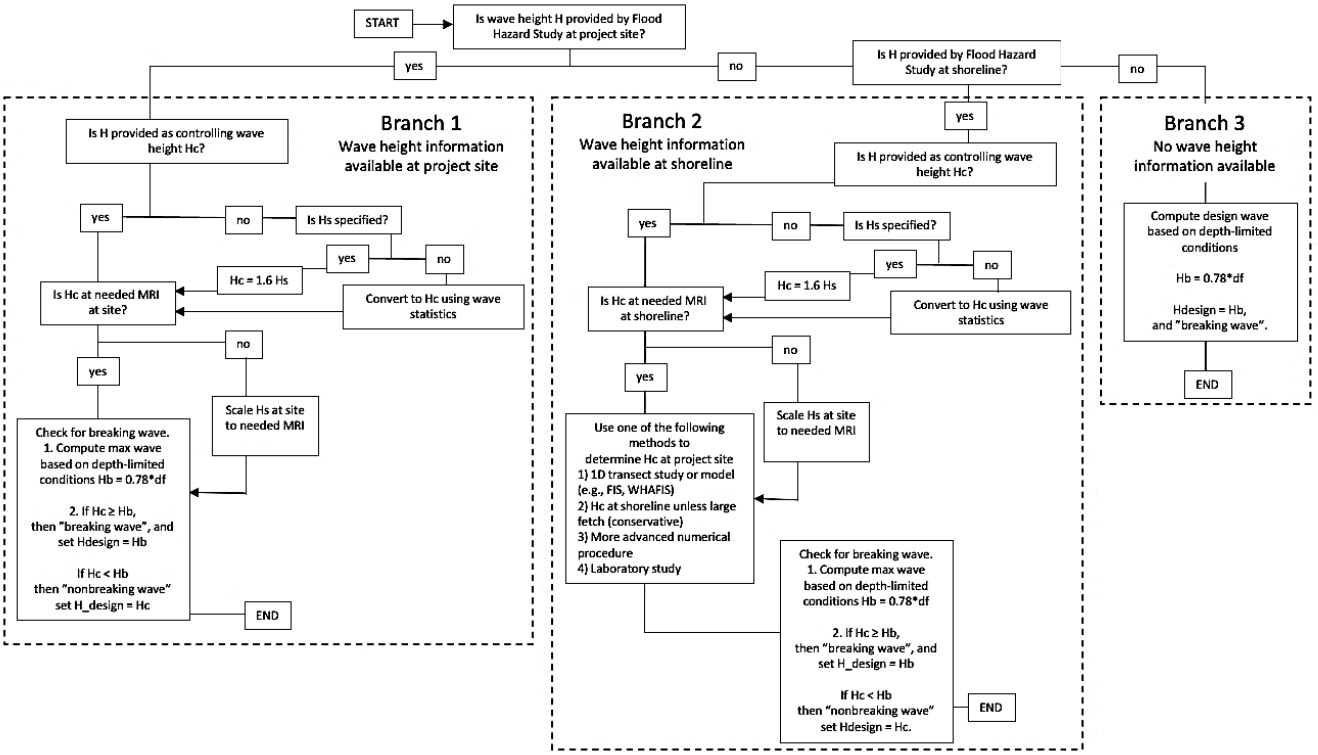


Figure C5.3-9. Procedure to Determine Wave Height at Site for Breaking and Nonbreaking Waves.

C5.3.7.2 Wave Period and Wavelength

Equation (5.3-9) can be used to estimate the wave period based on the design wave height. However, designers should consider additional sources to estimate the wave period such as a flood hazard study for that area. Designers should be aware that the wave periods from hurricanes at a coastal site exposed to the ocean can be in the range of 12 to 20 s.

Equation (5.3-10) relates the wavelength to the local water depth and wave period. For a local water depth of 16.4 ft (5 m) and for wave periods in the range of 12 to 20 s, the wavelength is in the range 269 ft (80 m) to 441 ft (134 m).

C5.3.8 Scour

The term *scour* indicates a localized lowering of the ground surface during a flood due to the interaction of currents and/or waves with a structural element. Scour is a complex mechanism related to hydrodynamic forces that causes local increases in bed shear stresses and the resulting sediment transport. Clays, silts, sands, and gravels are generally considered erodible when they can be moved under the design velocities. Paved surfaces, rock formations, and armored protection specifically designed for scour prevention are considered non-erodible when they

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cannot be moved under the design velocities. Vegetation is sometimes used as a means of stabilizing land and protecting against scour. However, the level of protection against scour is variable depending on the flood conditions, the elevation and slope of the planted surface, and the type, size, and density of the vegetation provided. If vegetation is being considered as part of scour protection, it should be maintained and carefully evaluated for its ability to stay in place during flooding, and to resist flood loads up to and during the design flood conditions.

While scour is a function of soil particle size, waves, and currents, the predictive equations for scour depth in general are empirically derived from small-scale laboratory tests and are relatively simplistic. Scour theory and studies for various coastal structures are discussed in depth in the *Coastal Engineering Manual* (USACE 2002). ASCE 24 requires that foundations extend to a depth sufficient to provide support to the structure taking into account the effects of scour. Scour is considered for evaluation of unbraced pile length, pile capacity, and review of undermining of foundations and walls. Unlike the effects of erosion, local scour does not affect the calculation of the design flood depth at a site or increase the wave height.

The methodology for scour calculation in this section is derived from USACE (2002) specific to coastal sites. Scour at riverine sites is different from coastal sites and is a common aspect of bridge foundation design. FHWA provides an industry standard resource for evaluating scour at bridges (2012) that can be adapted for scour calculations at riverine sites. Because the FHWA standard is intended for bridges, adaptation of these methods for buildings should be used with caution by the designer.

C5.3.8.1 Scour at Walls

The scour depth prediction methods are based on the *Coastal Engineering Manual* (USACE 2002) in EM 1110-2-1100 – Part VI, Change 3. The methods assume the erodible bed is composed of noncohesive sediment. Methods for predicting scour depth of cohesive soil are virtually nonexistent; however, estimates for scour of noncohesive erodible bed are expected to provide conservative estimates of the scour depth.

Part VI of the *Coastal Engineering Manual* (USACE 2002) discusses scour for nonbreaking wave using the results from 12 movable-bed model tests and concludes that uniform, regular nonbreaking waves produce a repeating pattern of scour and deposition as a function of distance from the toe of the vertical wall. For fine sand, the maximum scour nearest the wall occurs at a distance of $L/4$ from the face of the wall, where L is the wavelength. Waves with a relatively short period (2 to 3 s) in shallow floodwater depths [10 ft (3.05 m)] can have wavelengths between 20.4 ft (6.2 m) to 41.8 ft (12.7 m), in which case, the scour due to nonbreaking waves can occur close to the wall and may undermine the soil support. Hence the standard conservatively requires the scour to be considered at the face of the wall. Scour due to breaking waves occurs at the face of the wall and is generally greater than the scour depth for nonbreaking waves.

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C5.3.8.2 Scour at Vertical Piles and Columns

The provisions regarding vertical pilings and columns referenced in this section are based on small diameter piles (such that the pile diameter is less than one-tenth of the incident wavelength), and as such do not significantly affect the incident wave. The pilings and columns for buildings and other non-bridge structures generally fall in this category. Recommendations for large diameter piles can be found in the *Coastal Engineering Manual* (USACE 2002).

Scour has been observed to extend deeper for pile groups in coastal buildings. In particular, low-lying buildings with predominantly silty soils at grade are most susceptible to pile group scour. The interaction of waves and currents on pile groups is dependent on flow characteristics, wave conditions, pile size, and spacing. The potential for group effects in scour depth calculation should be evaluated based on available historical records and factors affecting pile scour. An estimate for scour around a pile group is given in Chapter 8 of FEMA P-55 (FEMA 2011), based on field measurements taken after flood events.

C5.3.9 Debris

Section 5.3.9 establishes the design requirements relating to debris effects. There are two types of debris effects considered in these provisions: debris damming and debris impact. Floods typically carry large amounts of objects that cannot resist the effects of flood loads and become dislodged from the ground or mooring. Floods with a depth less than 3 ft (0.91 m) are typically not capable of generating debris fields causing debris strikes or accumulation (damming) because objects drag along the ground due to the geometry of the element, and undulations in the topography. Therefore, if the site of interest has a design stillwater flood depth less than 3 ft (0.91 m), debris impact loads and debris damming do not need to be considered.

C5.3.9.1 Debris Impact

Based on the highly variable nature of water flow, with many load cases of different flood depths [including depths ranging from the design stillwater flood depth down to the threshold depth of 3 ft (0.91 m)] and flow directions, the most severe impact load location and direction must be considered. For example, in flexure this is often mid-height of a column in its weak axis. Impact loads must be applied at all locations at or below the design stillwater flood depth, with the corresponding hydrostatic and hydrodynamic loads, to determine the most severe location. It is permitted to not reduce the hydrostatic and hydrodynamic loads from the design stillwater flood depth while varying the impact load depth, but this may lead to very conservative loads.

In prior versions of ASCE 7, debris loads were only required for the 100-year flood zone. ASCE 7-22 Supplement 2 increased the design criteria to include the Shaded X-Zone (area between 100-year and 500-year flood) which increased the zone of debris requirements. However, a large portion of the shaded X-Zone has design stillwater flood depths (d_f) of less than the 3 ft (0.91 m) minimum threshold depth for debris, which will exempt much of the Shaded X-Zone from debris

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impact loads. Debris impacts are rare events; therefore, impact loads do not need to be considered simultaneously on multiple sides, planes, or panels of structural flood-resisting elements as the odds of multiple simultaneous debris impacts are minimal.

There are four exceptions to the debris impact requirements. Exception 1 is for when a designer has a site-specific study that shows definitive flow directions during the storm surge and recession, in this case debris impact need only be considered from the possible directions indicated in the study. The second exception occurs for riverine conditions where the flow direction is generally known, the debris strikes can be assumed to occur from the upstream direction with a +/-22.5 degree arc to account for some variation in flow. The third is an exception for one- and two-family dwellings. While flood driven debris impacts have been seen on single-family homes, this exception exists because the typical framing construction of these structures (light-framed wood) is not economical to design for a debris impact. The fourth exception is for Risk Category II structures outside the 100-year flood zone. This exception removes debris impact requirements for these structures between the 100-year and 500-year flood zones. Exceptions 3 and 4 only relate to debris impact requirements; design for debris damming is still required.

C5.3.9.1.1 Debris Impact Objects

It is not practical to consider all types of debris impacts for all risk categories of structures. Larger more rare debris impact strikes only need to be considered by more critical facilities that greatly affect a community's resilience. Debris objects considered in this chapter are wood poles/logs, passenger vehicles, small vessels (pleasure craft), shipping containers and larger vessels. These objects serve as proxies for the full suite of possible debris objects.

Table 5.3-4 is provided to summarize the debris types required for different structures based on risk category, threshold depth, and if façade (architectural components and deployed opening barriers) impacts are required to be checked. For all debris types the primary structural elements should be checked for debris strikes to provide life safety for the occupants of the building. However, unlike the majority of ASCE 7 provisions, whose focus is life safety, design for flood (through ASCE 24) also includes a focus on keeping habitable/occupied areas of buildings and other structures "dry." While dry floodproofing is not an explicit requirement of ASCE 7 to achieve this goal, it is critical that the façade, inclusive of opening barriers, remains intact and undeformed enough to meet permissible leakage standards, where structures are dry floodproofed. Table 5.3-4 attempts to balance these two purposes by including common, rational, debris objects for design of the watertight perimeter and rare, extreme debris objects for primary structure life-safety checks. Footnote 3 of Table 5.3-4 clarifies that the debris impact requirements apply only to nonload-bearing perimeter elements if part of a dry floodproofing system per ASCE 24. The smaller debris requirements for nonload-bearing (dry floodproof systems) is in alignment with ASCE 24 for limiting water damage in buildings by keeping the water out. The structural load bearing elements (defined as columns, walls, piles, and transfer

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beams) are checked for additional larger debris load types in addition to the smaller ones. These structural elements have been selected as elements critical for vertical stability of the structure to resist global collapse.

C5.3.9.1.2 Site Hazard Assessment for Localized Marine Debris, Shipping Containers, Ships, Small Vessels, and Barges

Large debris such as shipping containers and large vessels are often found in medium to large ports. These ports are often long distances from most significant structures. Even in extreme events these large debris objects have been observed to only travel limited distances.

Conversely, based on observations from previous events (e.g., Hurricane Katrina) large debris objects (shipping containers, ships, etc.) that start in an open area (i.e., harbor) can travel significant distances over open land/water but are limited in their travel over developed environments. Based on these field observations a two-step process was developed to determine the area of impact for large debris types.

Due to the observed travel sometimes exceeding 2 mi (3.2 km) over open land (FEMA 2006), the designer must first consider a 10,000 ft (3.03 km) radius from the source of the debris. (Note: for large debris sources, the radius should be taken from the worst-case edge of the source) over water or undeveloped land (i.e., water, beach, roads, open lots). From any point within that radius a second radius for travel into urban environments should be taken with a distance per Table 5.3-5. The travel distance is based on two factors: level of development (Moderate or Heavy) and the types of debris (shipping containers or ships/barges). A more developed urban environment will restrict the travel of debris; therefore, the radius considered is much smaller [500 to 2,000 ft (152 to 610 m)]. The definition of Moderate versus Heavy density is developed based on scaling of typical developed urban and suburban environments for building densities. When calculating densities, only structures that are tall enough (defined as 75% of flood depth) should be considered. In most flood zones, a one-story structure will have adequate height to meet this requirement. Additional information about debris transport under hurricane surge can be found in Kennedy et al. (2020).

An example of the site hazard assessment using a shipping container yard in Gulfport, Mississippi, is shown in Figure C5.3-10 and a second example with a container yard on an inland river is shown for Charleston, South Carolina, in Figure C5.3-11.

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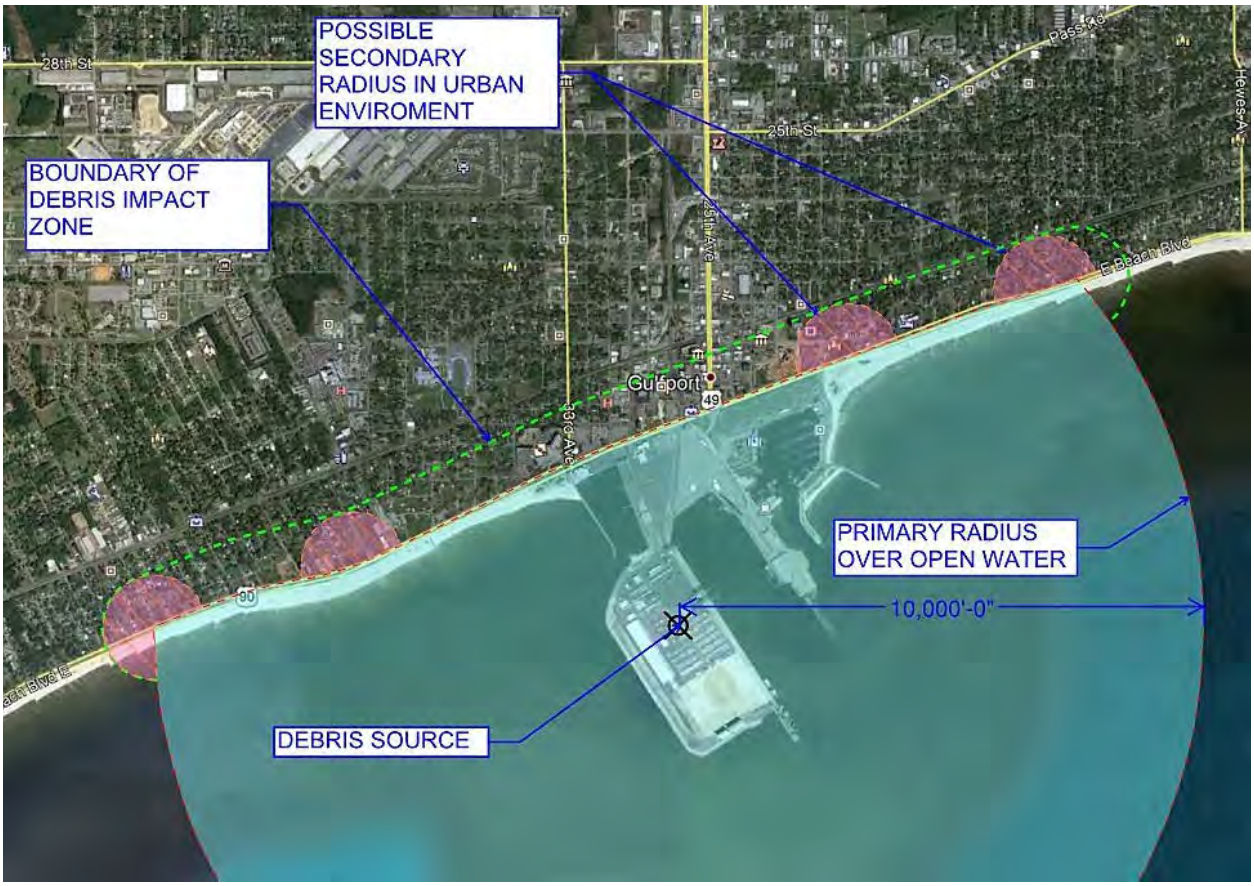


Figure C5.3-10. Example of Site Hazard Assessment for Container Yard in Gulfport, Mississippi.

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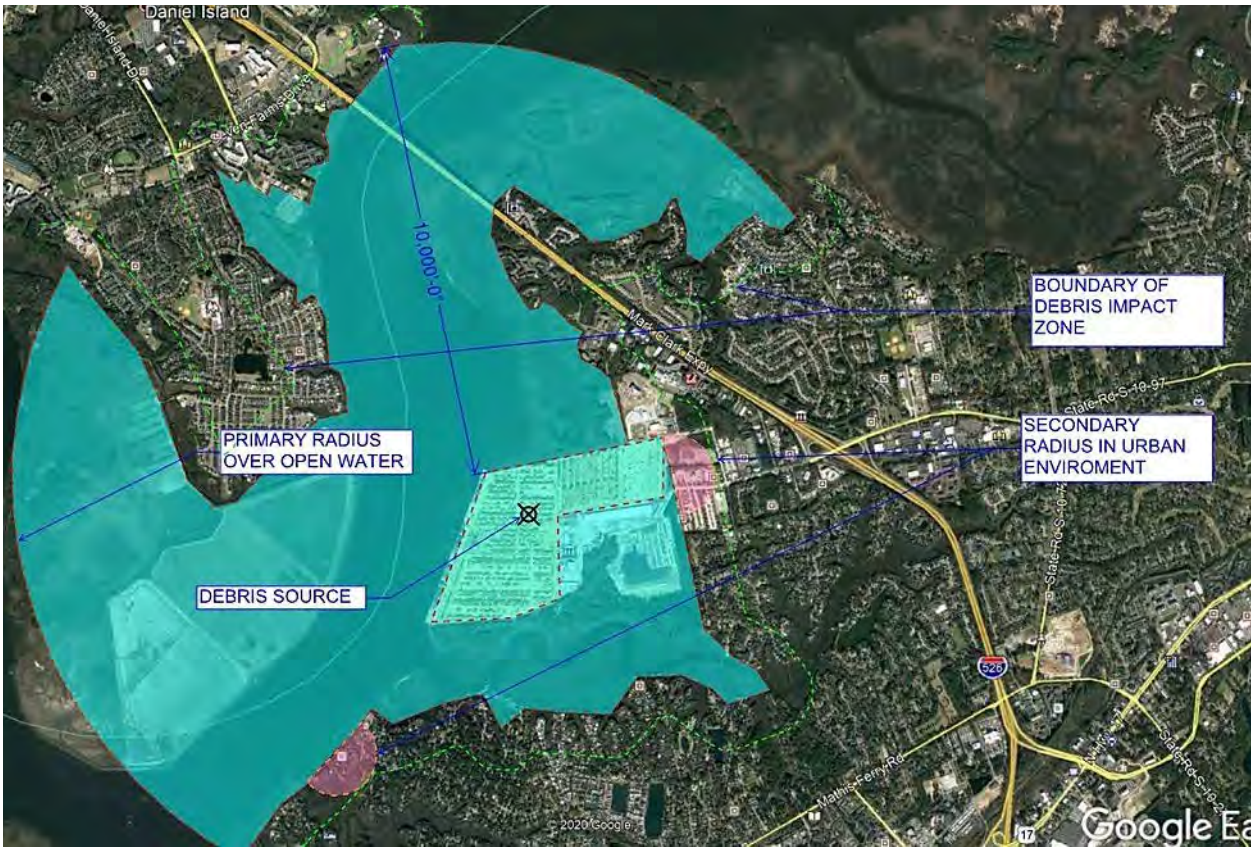


Figure C5.3-11. Example of Site Hazard Assessment for a Container Yard in Charleston, South Carolina.

Debris can become grounded based on lack of sufficient flow depth over local topography or substantial structures that would survive a design flood. Therefore, grounding may be considered to limit debris movements. For a debris type, if no viable path between the source of the debris and the site where the flood depth is greater than the threshold depth in Table 5.3-4, the debris type does not need to be considered.

ASCE 7-16 (and previous versions) of the debris loading commentary carried a blockage coefficient which talked about reduction in velocity of debris based on “screening and sheltering.” The intent of the current exception is if a design using rational methodology can show that a debris object cannot reach the building, design for this debris object can be neglected.

C5.3.9.1.3 Extraordinary Debris Impact Loading

Consideration of extraordinary debris is only required for Risk Category IV structures with a design stillwater flood depth of 12 ft (3.7 m) or greater. This provision is intended to protect the most critical buildings with the largest community resilience hazard. The designer is required to consider the largest vessel in the area (determined by the project site). Instead of directly

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designing for a vessel of this size, which is likely not economically practical, the designer is required to consider the loss of a structural element (i.e., a column) in a progressive collapse analysis.

C5.3.9.2 Debris Damming

Debris damming is the effect of debris becoming entangled with open structures, which causes increased drag forces on individual elements and the entire structure. Structures near the coast often have foundations that consist of individual columns/piles up to the first floor level; the spacing of these piles can vary from tightly spaced less than 10 ft (3.05 m) to larger spans greater than 30 ft (9.15 m). The ability of debris to start the damming between columns is a function of the spacing between the columns and the size and type of debris. Figure 5.3-1 provides a closure ratio that the engineer is required to use to calculate the hydrodynamic drag, which is based on the clear spacing of these vertical elements perpendicular to the flow. The closure ratio is defined as the fraction of space between the columns that needs to be considered as closed for design of these vertical elements for hydrodynamic loading. In addition, for open structures or structures with breakaway walls per Section 5.3.10 the debris damming needs to be considered for the design of the lateral force resisting system. Because the debris is surrounded by water, the debris dam does not impart additional hydrostatic loads in the horizontal direction. At vertical elements with clear spacing of 10 ft (3.05 m) and less, the closure ratio is 0.7 (i.e., 70% of that opening must be considered closed). The lower threshold of 10 ft (3.05 m) clear was set based on the debris types that are likely to be able to cause significant damming (i.e., cars). These objects exceed the 10 ft (3.05 m) clear distance in length but the likelihood of a 16 ft (4.9 m) car getting stuck on adjacent columns goes down as the column clear spacing exceeds 10 ft (3.05 m). At vertical elements with clear spacing of 30 ft (9.15 m) and greater, the probability of substantial debris being caught against the structure is minimal.

The spacing where damming effects can be neglected was established by review of post-hurricane field studies. The 30 ft (9.15 m) span was chosen because it exceeds the length of most debris types such as logs, cars, and small vessels which could cause the damming. The limit of 70% closure was established as the maximum for the closure ratio based on observations of debris damming in flood events. The requirement for a structure to consider two adjacent bays of debris damming ensures that a given column or wall sees a proper flood drag load due to damming on either side. The minimum requirement of two bays or 50 ft (15.2 m) is set based on the probability of seeing a large width building with debris accumulating over the entire width, which could unnecessarily increase the demands on the lateral force resisting system. The section points the designer to Section 5.4.3 for use of the closure ratio in the hydrodynamic drag forces section.

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C5.3.10 Loads on Breakaway Walls

Floodplain management regulations require buildings in coastal high hazard areas to be elevated to or above the design flood elevation by a pile or column foundation. Space below the ASCE/SEI 24 Design Flood Elevation (DFE) must be free of obstructions to allow the free passage of waves and high-velocity waters beneath the building (FEMA 2020). Floodplain management regulations typically allow space below the DFE to be enclosed by insect screening, open lattice, or breakaway walls. Local exceptions are made in certain instances for shear walls, firewalls, elevator shafts, and stairwells. Check with the Authority Having Jurisdiction for specific requirements related to obstructions, enclosures, and breakaway walls.

Where breakaway walls are used, NFIP regulations require that the walls meet certain prescriptive load requirements or be certified by a registered professional engineer or architect as having been designed to meet the NFIP performance requirements. Meeting the NFIP performance requirements means that the structure to which breakaway walls are attached should withstand both of the following: (1) load combinations, including flood loads acting on the structure and the breakaway walls, at the point at which breakaway occurs, and (2) load combinations for the full flood design loads, assuming the breakaway walls have detached.

The structure should be designed for the expected loads transferred from the breakaway walls and partitions to the structure. Loads on breakaway walls and partitions are usually calculated without using a material reduction factor (i.e., without phi-factor) and usually calculated assuming that actual yield or ultimate strengths are larger than the minimum strengths usually specified in new design. An approach similar to that used to compute expected strength in ASCE 41 could be used.

The NFIP prescriptive minimum breakaway load requirement of 10 psf (0.48 kN/m^2) has been adjusted in ASCE 7 to reflect Load and Resistance Factor Design methodology. Inasmuch as wind, earthquake, or lateral earth pressure loads may exceed the 100-year flood load, breakaway walls may be designed for higher loads, provided the design conditions of Section 5.3.10 are met. FEMA (2021) provides guidance on how to meet the performance requirements for certification.

C.5.3.11 Site-Specific Studies

This standard has been developed to conservatively establish the flood hazard, and therefore the associated flood loads, for buildings and other structures. Use of a site-specific study can result in a lower estimate of flood loads. Also, while the Standard mandates the flood hazard be considered from all possible directions, a site-specific study may be able to eliminate some possible directions after a full cycle of inundation and recession is considered.

Table 5.3-6 provides maximum allowable reductions from the velocity and wave height and period computed from Sections 5.3.6 and 5.3.7 for site-specific studies with and without peer review per Section 1.3.1.3.4. Velocity and wave height and period hazards can have large variability overland due to local conditions such as topography that have a greater effect on waves and currents than flood depth. Figure C5.3-8, for example, shows a large variability in the velocity simulated numerically for a given flood depth. Buildings and other obstacles can also influence the velocity and wave conditions, potentially leading to large reductions in velocity and wave height and period beyond the values in Table 5.3-6 (NAS 1977, East et al. 2008, Tomiczek et al. 2014). Velocity and wave height reductions reduce the hydrodynamic and wave loads in this chapter. Wave height and period reductions reduce the amount of scour considered at walls. However, the maximum allowable reductions provided in Table 5.3-6 are intended to provide reasonable limits that substantially reduce the potential for underestimation of velocity and wave height and period.

Site-specific studies may range from relatively simple to complex. The simplest studies use better topographic information in conjunction with hydrologic and hydraulic parameters established by the flood hazard study adopted by the Authority Having Jurisdiction. The more complex involve more accurate topographic information and re-estimation of one or more of the hydrologic and hydraulic parameters using numerical, statistical, or physical models and procedures accepted by the Authority Having Jurisdiction. Some site-specific studies may extend design flood parameters to higher MRIs than those contained in the adopted flood hazard study. Site-specific studies may account for the effects of local topography and development/land use on water surface elevations and flow fields, and in coastal areas, wave fields. Site-specific studies can reveal local variations in design flood conditions and erosion, including those resulting from channeling and sheltering by buildings and other structures.

C5.3.12 Performance-Based Design.

Performance-based design (PBD) methods are expected to yield flood design alternatives for Risk Categories II, III and IV structures for a design equivalent to the code-required minimums. There are many structures, such as multi-family housing, hospitals, assembly areas, and even hazardous chemical sites, that are in a special flood hazard area and, if undergoing substantial improvement or repair of substantial damage after a flood, might be required to be elevated to or above the DFE, and thus are faced with a decision to abandon the site or expensively renovate the structure to comply with the building code and NFIP flood regulations. Many existing buildings and some new buildings cannot feasibly be raised to comply with flood elevations, but owners might be able to improve their resilience and service to the community by selectively improving the performance of their most flood-vulnerable operational systems and/or their building access.

In addition, new commercial and industrial buildings are currently allowed to dry floodproof the entire facility and comply with the code, but they are not allowed to evaluate and choose to

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protect only the critical, isolated operational functions that are located within the flood depth. PBD allows this as a code compliant option if the design can demonstrate performance objectives of the facility are met. Also, new residential buildings, including multifamily buildings, are required to be elevated to be code compliant. As such, lobbies and other entrances for these structures must also be elevated in order to be code compliant. This provision will assist the owner in meeting the code if the PBD process demonstrates such spaces can meet the expected building performance if used for nonresidential purposes.

An independent peer review by qualified experts is required per Section 1.3.1.3.4 for flood PBD, similar to wind and earthquake.

The designer should help building owners evaluate the flood risk of their building and mechanical systems in conjunction with the desired performance of these systems during and after flooding. Based on the expected performance at various risk levels, the designer should determine which elevations or flood resistant design techniques will achieve the expected performance. Once the design risk level (the flood design return period) has been determined, then the designer can determine how best to achieve the selected risk level. This may be done with elevation, with floodproofing structures, with building hardening, with alternative technologies so some mechanical systems could be eliminated, or other resilience enhancing techniques.

The performance objectives should be framed by defining performance levels and then describing the expected performance of various risk category buildings when impacted by various flood hazard levels. The flood hazard levels should be defined by the Mean Recurrence Interval (MRI) in years. There are many ways to select the appropriate flood hazard level. Table C5.3-3 provides a listing of various MRI in years and their associated exceedance probabilities for three different lifespans (50 years, 75 years, and 100 years). The larger the MRI (return period), the less frequent the event but the greater the consequences of that event.

Table C5.3-3. Exceedance Probabilities.

MRI (yrs)	P (50)	P (75)	P (100)
10	99.5%	100.0%	100.0%
50	63.6%	78.0%	86.7%
100	39.5%	52.9%	63.4%
200	22.2%	31.3%	39.4%

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500	9.5%	13.9%	18.1%
700	6.9%	10.2%	13.3%
1,000	4.9%	7.2%	9.5%
2,000	2.5%	3.7%	4.9%
2,500	2.0%	3.0%	3.9%

The table suggests that for a building life of 50 years, the 100-year MRI event has a 39.5% chance of being equaled or exceeded during that lifespan. For the same lifespan, the 1000-year MRI event only has a 5% (4.9%) chance of being equaled or exceeded during that lifespan. Many Risk Categories III and IV structures would expect to have a greater than 50-year life. A NIST study focused on how to approach designs for immediate occupancy (NIST 2018) and suggested there might be three hazard levels: routine (serviceability), design (affects the building), and extreme (affects the community). It is recommended that the routine or serviceability hazard level be the 100-year MRI; the design level hazard should be at least 500-years for Risk Category II structures, which would make the coastal hazards of wind and flood have similar risk levels (wind has a 700-year MRI for Risk Category II structures, a 1700-year MRI for Risk Category III structures and a 3000-year MRI for Risk Category IV structures); the hazard level for the extreme event could be an event of any frequency greater than 1000 years, as long as it is established with the community and building owners/operators as part of the stakeholder group. Minimum design flood MRIs are provided in Table 5.3-1 of the standard.

Table C5.3-4 illustrates a matrix of expected performance and hazard levels for structures in accordance with their risk category (as used in Section 1.5.1 and Table 1.5-1 of ASCE 7). For flood hazards, unlike other hazards, it is assumed that all occupants have been evacuated prior to the event for structures in Risk Categories I through III.

Table C5.3-4. Matrix of Expected Performance and Hazard Levels for Flood.

Hazard Level versus Performance	Operational	Repairable	Significant Damage	Unsafe to Occupy
Routine	RC IV, RC III	RC II		
Design	RC IV	RC III, RC II		

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Extreme		RC IV	RC III	RC II

The performance levels shown in Table C5.3-4 are defined as follows:

Operational: This performance level suggests that however the building owner defines operational is how the flood design should be approached. For Risk Category IV structures the building must be operational during a routine event. This performance means that the occupants should not get wet while in the building, that the occupants should be able to travel to and from the structure just prior to and immediately after the event, and that the functional parts of the facility are operational such as water, sewer, heating, or cooling systems. For Risk Category IV structures, the operational aspects mentioned above would be required for design level events.

Repairable: This performance level suggests that the structure should be repairable after a given event which might include clean up, replacement of small elements of the mechanical or electrical systems, suggesting a reasonably short period of downtime. Repairable could also be defined as more extensive repair to portions of the mechanical or electrical systems or to the building envelope as long as the structure could safely be re-occupied. Likely there has been some water intrusion and finishes will need to be replaced locally to repair damage and inhibit mold growth. The influence of weather may need to be considered (i.e., in winter, if the heating system is not working, then occupancy may not be achievable or desirable).

Significant Damage: This performance level, also known as a “yellow tagged structure” in the ATC 45 system, suggests that there is no fear of collapse, but there was potentially significant water infiltration. Occupants should be able to return after the event to start the effort of removing debris, damaged systems, non-load bearing, partition walls, and finishes. There might be flood-borne debris that has impacted the structure, but this debris did not damage the building frame in a way that might cause a partial collapse of primary elements.

Unsafe to Occupy: This performance level, also known as a ‘red tagged structure’ in the ATC 45 system, suggests that there is significant damage to the structural frame, especially the foundation. There could be severe undermining of the footings from scour or erosion; there could be damage to the foundation walls or footings from large flood-borne debris, and the severity of the scour at the structural walls might make entry hazardous.

ASCE has quantified expected structural reliabilities for components that are necessary to provide a consistent risk-based design for the various risk category structures and for various hazard levels as defined by the MRI. These reliability targets are provided in Section 1.3.1 in ASCE 7.

The designer should follow the performance-based design procedures provided in ASCE 7 Section 1.3.1.3. There has been little research on fragility functions of structural members

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subject to various flood loads, so the designer should anticipate that some fragility functions will need to be developed and independently verified before using them for PBD.

C5.4 LOADS DURING FLOODING

C5.4.1 Load Basis

Water loads are the loads or pressures on surfaces of buildings and other structures caused and induced by the presence of floodwaters. These loads are of two basic types: hydrostatic and hydrodynamic. Wave loads can be considered a special type of hydrodynamic load and consist of nonbreaking or breaking wave loads. Debris loads are of two basic types: debris impact loads and debris damming loads. Debris impact loads result from objects transported by floodwaters striking against buildings and other structures or parts thereof. Debris damming loads result from the accumulation of debris on a structure subjected to flowing water.

C5.4.2 Hydrostatic Loads

Hydrostatic loads are those caused by water at rest and the resulting pressure exerted on inundated objects. Hydrostatic loads can occur either above or below the ground surface, from water that is free or confined within a structure. These loads are equal to the product of the hydrostatic pressure multiplied by the surface area on which the pressure acts.

Hydrostatic pressure at any point is equal in all directions and always acts perpendicular to the surface on which it is applied. The magnitude is proportional to depth as shown in Figure C5.4-1. Hydrostatic loads acting on inclined, rounded or irregular surfaces should be calculated based on the geometry of the surfaces and the distribution of hydrostatic pressure. Hydrostatic pressures may be used for structural calculations or may be resolved into vertical downward or upward loads (uplift or buoyancy) and lateral loads for simplified use based on the geometry of the surfaces and the distribution of hydrostatic pressure.

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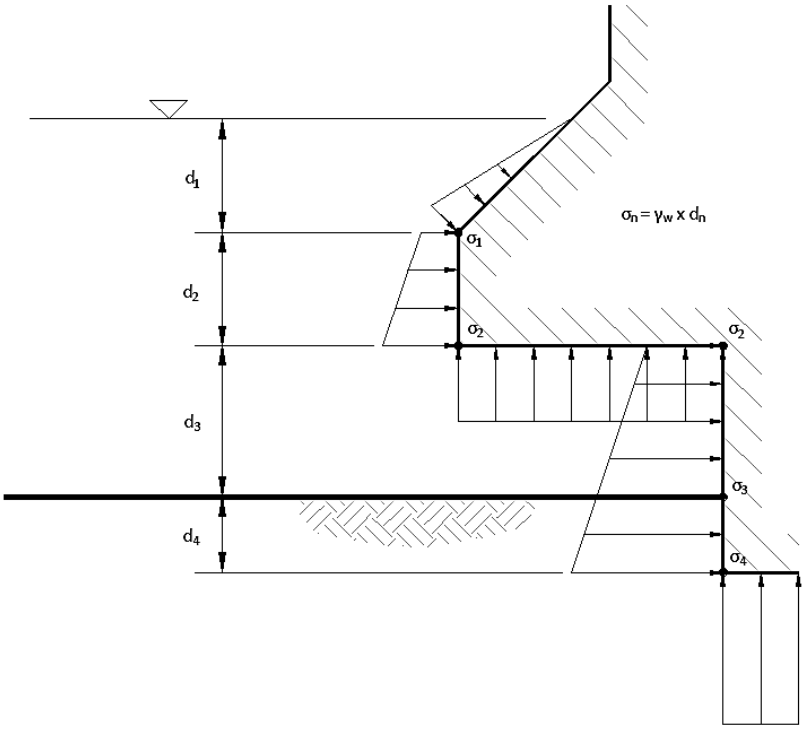


Figure C5.4-1. Example Hydrostatic Pressure Distribution.

C5.4.2.3 Seepage

The state of saturation of the soil and the location of the phreatic surface during and after a flood will dictate the hydrostatic loads applied to the portions of structures below grade. The rate of seepage of floodwaters through soils around and underneath a structure is affected by different factors including ground surface and soil permeability, time of inundation, and the flow path of water through soils. For short-term increases in water depth, such as during coastal storm surge, soils adjacent to or beneath a structure may not become fully saturated during a flood event and designing for full hydrostatic pressures below grade may be overly conservative.

Mitigation of seepage using active stormwater control systems (i.e., sump pumps) can be included at the discretion of the owner and engineer. A seepage analysis can also be used to evaluate the design discharge rate for the purposes of sizing these systems. The reliability of these systems should be evaluated with regards to long-term storage, regular maintenance, and a back-up power supply, to ensure proper operation during flood events.

C5.4.3 Hydrodynamic Loads

Hydrodynamic loads are those loads induced by the flow of water moving above the ground level. They are usually lateral loads caused by the impact of the moving mass of water and the

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drag forces as the water flows around the obstruction. Hydrodynamic loads are computed by recognized engineering methods. In the coastal high hazard area, the loads from high-velocity currents due to storm surge and overtopping are of particular importance. The *Coastal Engineering Manual* (USACE 2002) is one source of design information regarding hydrodynamic loadings.

C5.4.3.1 Drag Force on Components

This section provides the hydrodynamic drag equation (5.4-4) for individual components of structures (i.e., walls and columns). Each element of the structure exposed to the flood load should be checked for the component drag load. The C_{cx} coefficient accounts for accumulation of debris between vertical elements that effectively increases the tributary width on a vertical element. The C_{cx} coefficient is determined per Section 5.3.9.2. For individual elements both sides of the column or wall are considered to have debris damming.

C5.4.3.2 Drag Force on Lateral Force Resisting System

This section uses the same hydrodynamic drag equation to establish the overall force on the structure's lateral force resisting system. For buildings with solid walls, Equation (5.4-5) is used to determine the drag force on the structure. For open buildings or buildings with breakaway walls the drag force is a summation of the drag on individual components (i.e., columns and walls). In addition, debris damming needs to be considered per Section 5.3.9.2 that will increase the effective tributary width of the element. While for component design all vertical elements need to consider this damming it is not reasonable to consider every column with this increased drag simultaneously thus the requirements of Section 5.3.9.2 limit the number of bays that need to consider damming for the design of the lateral force resisting system.

C5.4.4 Wave Loads

Wave loads result from water waves striking a building or other structure. Design of buildings and other structures subject to wave loads should account for the following loads: waves interacting with a portion of the building or structure; uplift forces caused by waves beneath a building or structure, or portion thereof; wave runup striking a portion of the building or structure; wave-induced drag and inertia forces; and wave-induced scour at the base of a building or structure or its foundation.

The magnitude of wave forces (lb/ft^2) (kN/m^2) acting against buildings or other structures can be many times higher than wind forces under design conditions. Thus, elevating the structure above the wave crest elevation is crucial to the survivability of buildings and other structures. The portion of the elevated structures located within the design stillwater flood depth must be designed for large wave forces.

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Wave load calculations using the analytical procedures described in this standard ~~all~~ depend on the initial computation of the wave height and period described in Section 5.3.7.

C5.4.4.1 Wave Loads on Vertical Piles and Columns

Breaking wave loads tend to be significant, particularly on vertical piles or columns. Floods loads primarily exert lateral loading, and slender foundation elements should be designed for these loads both structurally and geotechnically. In general, the lateral load exerted on piles are resisted by soils with depth and will result in larger bending moments compared to assuming fixity at grade. This soil-structure interaction is typically taken into consideration by developing inelastic soil (*p-y*) springs to represent soil resistance at depth along the length of the pile, or by developing an equivalent depth to pile fixity without soil springs. For the latter approach, the depth to the point of fixity shall be determined at the depth that produces the same top of pile displacement as that given by an individual lateral analysis for a given lateral load at the top of pile.

C5.4.4.1.1 Nonbreaking Wave Loads on Vertical Piles and Columns

The maximum net wave force due to a nonbreaking wave is based on a publication by the US Army Corps of Engineers (USACE) (2002). The isolines contained in the figures (Figures VI-5-131 to VI-5-134 of USACE 2002) are used for development of the force coefficient.

While ϕ_m often can be lower than 0.5, the standard has conservatively considered the maximum possible force coefficient for the wave loading formula. If permitted by the Authority Having Jurisdiction, for round piles or round columns, other values of ϕ_m may be used based on Figures VI-5-131 to VI-5-134 of USACE (2002). The wave force should be considered to act at the design stillwater flood elevation; however, Figures VI-5-135 to 138 of USACE (2002) can be used for estimation of the moment generated by the wave forces at the groundline. The moment at the groundline when divided by the net wave force yields the location of the wave force with respect to the groundline.

When *W* exceeds 1.0, the Morrison equation, which is the basis for USACE (2002) figures, is no longer applicable, in which case the vertical pile or column behaves as a wall. Therefore, the formulae for nonbreaking wave loads on non-elevated vertical walls may be used for wave force determination.

The wave drag coefficient, C_D, varies depending on the Reynold's Number, R_e, according to the following relationship:

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$$C_D = \begin{cases} 1.2, \text{ where } R_e < 1 \times 10^5 \\ 1.2 - \frac{R_e - 2\times10^5}{6\times10^5}, \text{where } 1 \times 10^5 < R_e < 4 \times 10^5 \\ 0.7, \text{where } 4 \times 10^5 > R_e \end{cases} \quad \text{(C5.4-1)}$$

where

R_e = Wave Reynolds number given by:

$$R_{e=} \frac{u_m D}{\nu} \quad \text{(C5.4-2)}$$

and where

ν = Fluid kinematic viscosity in ft^2/s (m^2/s). For seawater, ν = 1.21E-5 ft^2/s (ν = 1.12E-6 m^2/s), and for freshwater, ν = 1.08E-5 ft^2/s (ν = 1.00E-6 m^2/s)

u_m = Maximum horizontal velocity in ft/s (m/s) given by

$$u_m = \frac{g\, H_{design}\, T_p}{L} \quad \text{(C5.4-3)}$$

Typically, for shallow water waves, R_e is greater than 4×10^5. Therefore, the standard incorporates a drag coefficient of 0.7 for round columns or piles.

Research on wave drag coefficients for square or rectangular cylinders is limited. An experiment carried out by Venugopal et al. (2006) indicated that the range for C_D is 2.0 to 4.0 for KC > 3.0, where KC is Keulegan-Carpenter number. KC is generally over 10 for shallow water wind driven waves. Therefore, a drag coefficient of 2.25 has been incorporated in the standard, which is also consistent with the breaking wave formula in the standard.

C5.4.4.2.1 Lateral Nonbreaking Wave Loads on Non-elevated Vertical Walls

Equations for nonbreaking wave loads on vertical walls presented in Section 5.4.4.2.1 are based on the methodology proposed by Goda (1974) and presented in USACE (2002), Goda (2010), and Tomiczek et al. (2019). Equations presented in Section 5.4.4.2.1 are modified for non-elevated vertical walls on a horizontal submerged ground surface subject to normally incident water waves

The original equations were derived for nonbreaking waves acting on a vertical caisson breakwater elevated on a rubble mound with crest elevation at depth *d*, the base of the upright section at depth *h'*, and depth offshore of the breakwater at depth *h.* The horizontal pressure distribution is defined

$$\eta^* = 0.75\,(1+\cos(\beta))H_{design} \quad \text{(C5.4-4)}$$

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$$p_1 = \frac{1}{2}(1 + cos(\beta))(\alpha_1\lambda_1 + \alpha_2\lambda_2 cos^2(\beta))\rho_w g H_{design} \qquad \text{(C5.4-5)}$$

$$p_2 = \begin{cases} \left(1 - \frac{h_c}{\eta^*}\right) p_1 & for\ \eta^* > h_c \\ 0 & for\ \eta^* \leq h_c \end{cases} \qquad \text{(C5.4-6)}$$

$$p_3 = \frac{p_1}{cosh\left(\frac{2\pi h}{L}\right)} \qquad \text{(C5.4-7)}$$

$$p_4 = \alpha_3 p_1 \qquad \text{(C5.4-8)}$$

where all previously defined variables are consistent with Section 5.4.4.2.1 and

ρ_w = Density of water in lb s^2/ft^4 (kg/m^3), taken as 1.94 lb s^2/ft^4 (1000 kg/m^3) for fresh water and 1.99 lb s^2/ft^4 (1027 kg/m^3) for seawater, and

p_4 = Pressure in lb/ft^2 (kN/m^2) at the base of the structure.

Wave pressure coefficients α_1, α_2, and α_3 are calculated as

$$\alpha_1 = 0.6 + \frac{1}{2}\left[\frac{4\pi h/L}{sinh\left(\frac{4\pi h}{L}\right)}\right]^2 \qquad \text{(C5.4-9)}$$

$$\alpha_2 = min\left\{\frac{h_b - d}{3h_b}\left(\frac{H_{design}}{d}\right)^2, \left(\frac{2d}{H_{design}}\right)\right\} \qquad \text{(C5.4-10)}$$

$$\alpha_3 = 1 - \frac{h'}{h}\left[1 - \frac{1}{cosh\left(\frac{2\pi h}{L}\right)}\right] \qquad \text{(C5.4-11)}$$

with h_b defined as the water depth in ft (m) measured at a horizontal distance $5H_s$ seaward of the breakwater. Coefficients λ_1 and λ_2 account for breakwater geometry and are set equal to unity for a standard upright breakwater. For a horizontal submerged ground surface, h_b=d and therefore

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α_2=0. In addition, in the absence of a rubble mound $h=h'$ and the pressure at the bed equals the pressure at the base of the vertical wall or structure ($p_3=p_4$).

C5.4.4.2.2 Lateral Breaking Wave Loads on Non-Elevated Vertical Walls

Breaking waves are plunging waves that may impact a vertical wall or other structure with a nearly vertical front, inducing high magnitude, short-duration impulsive pressures (and associated force) on a wall or vertical structure. Breaking waves may also entrap air pockets that result in a double peaked force associated with the wave crest hitting the structure and subsequent air pocket compression. Breaking wave loads on buildings and other structures can be very large, and conditions resulting in frequent wave breaking at vertical walls and other structures should be avoided when possible. The equations proposed by Goda (1974) were modified to account for impulsive breaking wave pressures by Takahashi et al. (1994) and are presented in USACE (2002). Section 5.4.4.2.2 conservatively assumes that the impulsive wave breaking coefficient, α_{IB}, accounting for berm width, wavelength, and water depth is equal to 1.0.

The Goda (1974) equations for nonbreaking waves with modifications for impulsive wave breaking by Takahashi et al. (1994) have been compared to large and small- scale experiments measuring nonbreaking and breaking wave-induced loads on vertical walls and elevated structures. Predicted forces showed good agreement with laboratory measurements (e.g., Wiebe et al. 2014, Tomiczek et al. 2019).

C5.4.4.2.4 Lateral Breaking Wave Loads from Obliquely Incident Waves

Wave loads on vertical walls reach a maximum when the waves are normally incident (i.e., direction of wave approach is perpendicular to the face of the wall with wave crests parallel to the face of the wall). Obliquely incident waves may be identified by a site-specific study. In the absence of a site-specific study and as guidance for designers of coastal buildings or other structures on normally dry land (i.e., flooded only during coastal storm or flood events), it can be assumed that waves will approach the shoreline within a 22.5-degree angle from perpendicular. Therefore, the direction of wave approach relative to a vertical wall will depend upon the orientation of the wall relative to the shoreline.

Wave force equations provided in Sections 5.4.4.2.1 and Section 5.4.4.2.2 may be modified in instances where waves are obliquely incident. The pressures and forces from obliquely incident waves should be calculated by modifying Equations 5.4-8 and 5.4-9 (or 5.4-14). In the equations, η^* and p_1 (or p_{1B}) should be multiplied by

$$C_\beta = (1/2)\,(1 + \cos(\alpha_H)) \qquad \text{(C5.4-12)}$$

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where

C_β = Coefficient accounting for wave directionality, and

α_H = Horizontal angle between the direction of wave approach and the vertical surface.

C5.4.4.2.5 Lateral Wave Loads on Elevated Walls

Many near-coast structures are elevated above the ground on piles or piers and may experience both lateral and uplift forces during extreme storm surge and wave events. The Goda (1974) equations were modified for elevated structures by Wiebe et al. (2014) assuming a linear pressure distribution between either the pressure at the design stillwater flood elevation and zero pressure at elevation η^* (positive air gap) or the pressure at the design stillwater flood elevation and the pressure at the bed (negative air gap). Large and small-scale physical model experiments measured nonbreaking and breaking wave-induced loads on non-elevated and elevated vertical walls, with predicted forces showing good agreement with laboratory measurements (e.g., Wiebe et al. 2014, Tomiczek et al. 2019).

C5.4.4.3 Wave Uplift Forces on Elevated Structures and Non-Elevated Structures with Overhangs

Uplift forces on an elevated structure are a function of the structure's base dimensions, elevation with respect to the design stillwater flood depth, and wave conditions including wave height and period. Uplift forces have been observed to be significantly greater than horizontal loads, especially for small, nonbreaking incident wave heights. Park et al. (2017) measured horizontal and vertical forces on a 1:10 scale physical model structure and found that the maximum uplift force occurred when the structure's base was positioned at the design stillwater flood elevation. Particularly for small waves, the horizontal to vertical force ratio was less than one, indicating that peak vertical forces may exceed peak lateral forces. Regular wave measurements from the same experiments found a range of vertical to horizontal force ratios of 1.2 to 9.7. Bradner et al. (2011) performed 1:5 scale measurements on a bridge highway superstructure and measured vertical forces three to five times those corresponding horizontal forces.

USACE (2002) presents equations for estimating wave uplift forces due to steady and oscillatory currents or wave slamming. The uplift forces due to currents are considered when the width of the structure is small compared to the wavelength ($D/L < 0.2$), and is calculated as:

$$F_L = C_L A_N \gamma_w (u^2/(2g)) \qquad \text{(C5.4-13)}$$

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where

C_L = An empirical lift coefficient,

A_N = Projected area of the solid body normal to the flow direction,

γ_w = Ppecific weight of water, in lb/ft^3 (kg/m^3),

g = Gravitational acceleration, taken as 32.2 ft/s^2 (9.81 m/s^2), and

u = Magnitude of the flow velocity, in ft/s (m/s).

For steady flow situations, the empirical lift coefficient, C_L, is a function of the Reynolds number, the solid body roughness, and the boundary-imposed flow field around the body.

When the base of the structure is located above the design stillwater flood elevation and subjected to oscillatory wave action, the uplift force may be approximated as

$$F_U = C_U A_Z \gamma_w (w^2/(2g)) \qquad \text{(C5.4-14)}$$

where

C_U = Laboratory defined wave slamming coefficient,

A_Z = Projected area of the solid body in the horizontal plane, and

w = Vertical component of the flow velocity, in ft/s (m/s).

Sarpkaya and Isaacson (1981) noted laboratory measured slamming force coefficients, C_U, ranging from 4.1 to 6.4 for rigidly mounted horizontal circular cylinders.

Wave uplift forces on a partially submerged elevated structure are difficult to compute due to the modification of the flow field by the structure and nonlinear boundary conditions at the water surface. Physical and numerical modeling can provide estimates of wave uplift forces on elevated structures. Equations have been proposed that estimate the total uplift force on offshore platforms and coastal bridges; often equations are a function of one or more of the following: wave height, wave period, water particle velocity, and structural base dimensions (e.g., Kaplan et al. 1995, Suchithra and Koola 1995, Bea et al. 1999, Douglass et al. 2006, AASHTO 2008). Simpler formulae relating the elevation of the base of a structure with respect to the design stillwater flood elevation are proposed by Wang (1970) and Cuomo et al. (2011).

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C5.4.5 Debris Impact Loads

Impact loads are those that result from objects that can be picked up in flood events such as logs, cars, small vessels, and, in larger flooding events, shipping containers, barges, and large ships. Section 5.3.9 defines what debris strikes are applicable for each type of building and component (i.e., façade versus primary structure) and this section covers the specification of loads on structures and structural components by debris objects.

C5.4.5.1 Debris Impact Load Determination

Debris impact forces are to be determined for the location of the structure based on the potential debris in the surrounding area that would be expected to reach the site during the flood. Of particular concern are the perimeter structural components oriented perpendicular to the flow direction because they are at the greatest risk of impact and their loss may compromise the ability of the structure to support gravity loads.

The impact forces depend on the impact velocity, which is assumed to be equal to the flow velocity for floating debris. The points of application of the impact force, which is assumed to be a concentrated force, are chosen to give the worst case for shear and moment for each component that is required to be considered within the inundation depth and the corresponding flow velocity (as required in Section 5.3.9.1). Exceptions to this are specified in subsequent sections based on specific debris characteristics.

C5.4.5.1.1 Simplified Debris Impact Load for Passenger Vehicles or Small Vessels

Designing for a conservative, prescriptive load is allowed to replace specific consideration of impact by vehicles, and small vessels which are the debris types required for all structures. The prescriptive load is based on the maximum force generated based on the elastic procedure of Section 5.4.5.1.2. This assumes the maximum design velocity per Section 5.3.6 of 10 ft/s (3 m/s) and a very stiff structural element (24 in. wide by 14 in. thick concrete wall, remaining elastic k = 500 k/in). The result is controlled by the small vessel (41 kips with C_o factor applied) which is very conservative for most applications. This does not account for a more flexible structural element, the stagnation coefficient, the debris depth coefficient or that in most conditions, the design velocity will be much lower than the required maximum. In addition, this load does not account for inelastic behavior the debris element (i.e., crushing).

C5.4.5.1.2 Elastic Debris Impact Loads

Previous versions of this chapter (Section C5.4.5 of ASCE 7-16) have been based principally on an impulse-momentum formulation for rigid-body impact, which requires an assumption of the duration of impact. Conversely, Equation (5.4-20) is based on stress wave propagation in the debris and hence considers the flexibility of the debris and impacted element.

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The elastic debris impact equation in Section 5.4.5.1.2 is essentially a reformulation of the impulse momentum approach using the stiffness of the debris and element struck to establish the impact duration. This equation is a simple approach for determining the required impact forces and requires minimal information.

The primary assumption is the debris object remains elastic during impact and strikes the structure longitudinally. The stiffness is typically taken of the debris object assuming the impacted component is completely rigid, however the impacted component stiffness can be significantly less than the debris (in the case of a column or out of plane wall). If desired the lateral stiffness of the component can be included to determine an effective stiffness using Equation (C5.4-15):

$$k_{eff} = 1/(1/k_{debris} + 1/k_{structure}) \quad \text{(C5.4-15)}$$

The debris velocity coefficient (C_R) is a coefficient used in previous editions of this document (ASCE 7-10, C5.4.5) to recognize that in shallow flooding scenarios, bottom drag plays a significant role in the velocity of the debris. Thus, for flow depths of less than 5 ft (1.5 m) the effective debris velocity is reduced from the design velocity.

The value of the debris orientation coefficient, C_o, was derived from the data of Haehnel and Daly (2004), jointly sponsored by ASCE and FEMA. It is the mean plus one standard deviation value of the log debris impact force for trials that included glancing and direct impacts of freely floating logs. Therefore, C_o will remain as 0.80 used in prior versions of Chapter 5 to account for the less likely head-on strike of the object on a wall. The 0.80 factor correlates to an object strike that is approximately 36 degrees between the longitudinal axis of the debris and the flow direction.

The debris velocity stagnation coefficient, C_s, has been added for Chapter 5 based on recent laboratory testing and recognition that a more accurate load characterization was needed when an architectural component is the critical resisting element. C_s is a factor to locally reduce the velocity of the impacting debris based on the effect of water level increasing as it stagnates on the face of a wider building (refer to Figure C5.4-2). This is substantiated by testing as described in Shafiei et al. (2016) and Derschum et al. (2018) which observed that the debris velocity decreased as it approached a structure. This flow stagnation will significantly reduce the velocity of debris strikes to the building near the center. The factor provides a reduction in velocity based on location across the face of the building. The factor is limited to non-load bearing elements on the face of closed buildings (i.e., no flow through) and buildings wide enough to exhibit the effect. In addition, for stagnation to occur, there cannot be any open flow through the structure (i.e., open structure), flow below the structure (i.e., elevated structure), or walls cannot be designed to break away during flood loading. The stagnation effect is typically applicable for façade elements and their back-up framing subjected to the flood loading, not primary gravity structure such as columns located inside the façade. A graphical illustration of

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the effect is shown in Figure C5.4-2. The perpendicular flow velocity at the sides and the back of a building (relative to the direction of the flow) are significantly smaller than at the front corners. However, unless a site-specific study is performed to establish the flow direction, flow is required to be considered in all directions for coastal sites.

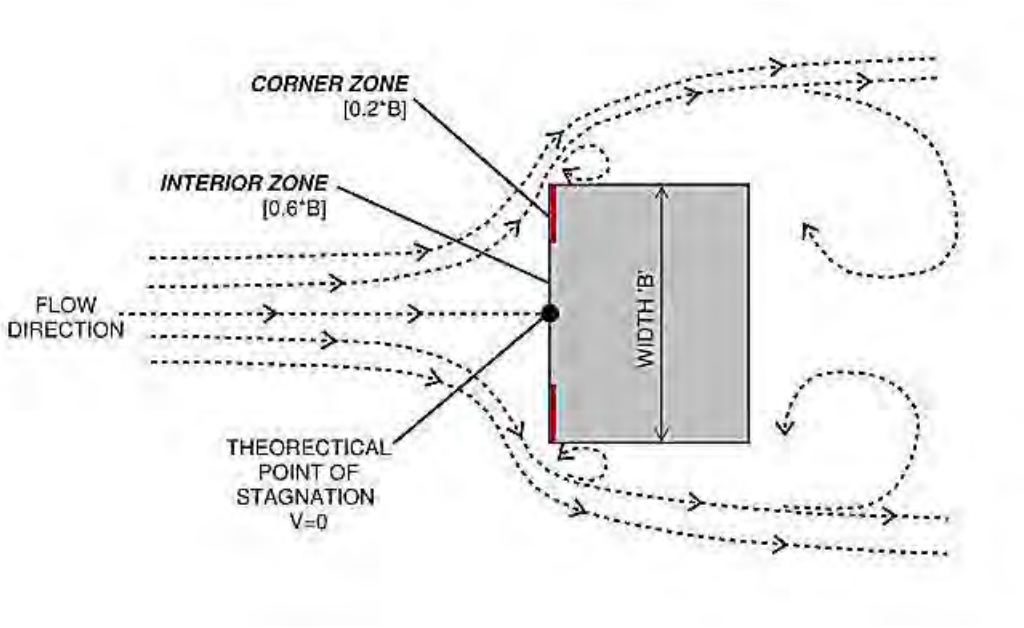


Figure C5.4-2 Flow Stagnation at the Face of the Building.

For some debris/structural elements, the assumption that the debris and structure remain elastic can be extremely conservative, resulting in significantly higher forces than may actually be observed. For most debris strikes, the impacted elements impacted will experience a response in their inelastic range; thus, the element will have a much lower effective stiffness. However, using a cracked or reduced stiffness can be unconservative if the proper analysis is not done. For example, a CMU wall seeing a debris strike will likely yield the reinforcing, crack the tension face of block and possibly see crushing at the compression face at the point of maximum moment. However, at the ends of the walls (in a pinned condition) the walls remain in their uncracked state. Using the work energy approach of Section 5.4.5.1.3, the effective stiffness of walls can be determined considering the changing effective stiffness over the wall height. If the methods of the elastic approach lead to failing elements by a reasonable margin, it is likely a more advanced approach using the structural elements' nonlinear response could be used to justify the elements adequacy. However, if this approach is taken, any permanent deformation or cracking must be evaluated against any dry floodproofing leakage performance, as defined in ASCE 24, of the watertight barrier (if any).

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C5.4.5.1.3 Alternative Methods of Debris Impact Analysis

It is permissible to use one of the following nonlinear methods in lieu of the elastic debris impact method of Section 5.4.5.1.2. An equivalent single degree of freedom mass-spring system with a nonlinear stiffness that considers the ductility of the impacted structure for the dynamic analysis is permitted to be used to determine the impact forces. Alternatively, the structural response is permitted to be calculated based on a work-energy method with nonlinear stiffness that incorporates the ductility of the impacted structure. The velocity used for this analysis is VC_RC_s C_o as defined by Section 5.4.5.1.2. Impact loads are to be applied to the structure over areas defined in Section 5.4.5.2 to produce the most critical flexural and shear demands.

Where debris impacts from shipping containers, ships and barges exceed the acceptance criteria of a structural element, it is permitted to accommodate the impact forces through progressive collapse provisions of the recognized literature. Progressive collapse provisions are applied up to the design stillwater flood depth plus the height of the deck of the vessel from the waterline.

C5.4.5.2 Debris Types and Properties

Wood Logs and Poles

The assumptions used to tabulate the debris stiffness for wood log and pole strikes are that the impact is elastic and that the pole/log is longitudinal when it impacts the structural element. That is, in the case of a pole or log, it hits the structure with its butt end rather than broadside. However, it is unlikely that a true longitudinal strike will occur in a turbulent flow over uneven ground. The orientation factor is provided to adjust for a non-longitudinal strike.

A 1,000 lb (4.5 kN) object can be considered a reasonable average for flood-borne debris and is consistent with ASCE 7-98 through ASCE 7-16. This represents a reasonable weight for trees, logs, and other large woody debris that is the most common form of damaging debris. This weight corresponds to a log approximately 30 ft (9.1 m) long and just under 1-ft (0 3-m) in diameter. The 1,000 lb (4.5 kN) object also represents a reasonable weight for other types of debris ranging from small ice floes to boulders to man-made objects.

However, design professionals may wish to consider regional or local conditions before the final debris weight is selected. In riverine floodplains, large woody debris (trees and logs) predominates, with weights typically ranging from 1,000 lb (4.5 kN) to 2,000 lb (9.0 kN). In the Pacific Northwest, larger tree and log sizes suggest a typical 4,000 lb (18.0 kN) debris weight. Debris weights in riverine areas subject to floating ice typically range from 1,000 lb (4.5 kN) to 4,000 lb (18.0 kN).

The elastic stiffness of the log can be established using structural mechanics (AE/L) for a Douglas fir larch pole 30 ft (10 m) long, measuring approximately 12 in. (0.3 m) in diameter. A stiffness of 350 to 550 kips/in (4,200,000 to 6,600,000 lb/ft) can be derived using structural

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properties from the National Design Specification (NDS). Lab testing sponsored by the USACE (refer to Haehnel and Daly 2002) showed the effective stiffness of a log is likely a fraction of the elastic stiffness calculated above. This testing set the upper bound of a straight-on impact at 2.4 MN/m, which correlates to a 14 kips/in (168,000 lb/ft) effective stiffness. However, more recent research (Piran Aghl et al. 2014) indicates a higher stiffness, consistent with the calculated elastic stiffness, which is used as the minimum requirement.

Vehicles

Passenger vehicles are ubiquitous, float, and are easily transported. This assumes that impact occurs, as long as the inundation depth is sufficient to float the vehicle, which is deemed to be 3 ft (0.91 m). Research by NCAC (2011, 2012) describes an experimental and numerical analysis of the frontal crash impact of a 2,400 lb (10.7 kN) subcompact passenger vehicle traveling at 35 mph (15.6 m/s) against a wall. Based on the results therein, the initial stiffness of the vehicle was estimated to be 5,700 lb/in (998 kN/m), which has been rounded up to 6 kips/in (72,000 lb/ft) (1,051kN/m). While it is acknowledged that larger, heavier, and stiffer vehicles are likely to be within the floodplain, the lighter compact style cars are most likely to float freely and are considered in this standard as a minimum. The designer may choose to evaluate a larger debris impact but the smaller car more likely to float is established as the minimum requirement.

Small Vessels

In a flood event. there is likely to be a number of small vessels (typically 16 to 30 ft) (4.9 to 9.1 m) in length in the flood area. These types of vessels are typically of aluminum, wood or fiberglass construction and are not ocean-going vessels. These debris objects are typically limited to vessels of 2,500 lbs (11.1 kN) due to their size and construction type thus this is established as a minimum stiffness for design. The stiffness required for design is the axial stiffness of the vessel (*AE/L*), with the largest stiffness coming from a straight-on bow impact.

These vessels are typically 6 to 8 ft (1.8 to 3.6 m), in width resulting in a maximum hull cross sectional length of approximately 100 to 150 in. (significantly less at the front at the point of impact). Thickness varies from 0.25 to 0.75 in., depending on location. Based on the size and length of these vessels and typical construction materials (elastic modulus approximately 10,000 ksi for aluminum) a minimum effective axial stiffness for a theoretical straight-on impact engaging the entire cross section could exceed 500 kip/in. However, the likelihood of a straight-on impact aligning with the point of the bow on a perpendicular surface is highly unlikely. Therefore, the effective stiffness of an offset impact on the bow region is considered for the minimum design stiffness. Based on a sample of small vessels considered with parametric studies showing slightly off-center impacts in the bow region an effective stiffness of 30 kips/in [360,000 lb/ft (5,254 kN/m)] is established as the minimum for design. This is significantly lower than the straight-on stiffness due to bending in the sidewalls of the vessel being considered. There may be vessels in this size range with effective stiffness higher than this value,

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however this was deemed as a reasonable minimum threshold for design. A designer should always consider local conditions that may result in a higher mass or effective stiffness.

Shipping Containers

Shipping containers, like cars, are likely to float in a flood event. These containers have been shown to reach the full water velocity and have significant mass. Test results (Piran Aghl et al. 2014) have shown that the mass of container contents does not significantly affect the impact force as long as the contents are not rigidly attached to the structural frame. Therefore, for shipping containers, the mass of the container without contents is used in Equation (5.4-20). Shipping containers are standardized in terms of length, height, and width, but weight and structural details can vary somewhat by manufacturer. The values for weight and stiffness provided in Table 5.4-4 are considered to be reasonable approximations for most standard ISO shipping containers. Hence, these numbers converted to mass can be used directly in Equation (5.4-20) for m_d. The stiffness values are based on EA/L, where E is the modulus of elasticity of steel, A is the cross-sectional area of one bottom rail of the container, and L is the length of the rail, not including any cast end blocks.

Equation (5.4-20) does not contain any factor to account for an increase in force caused by the fluid flow being affected by the sudden stoppage of the debris object, which some other formulations include. For longitudinal impact of a log, such an increase in force is not expected to be significant. Testing of scale-model shipping containers also showed that for longitudinal impacts, the impact force was not significantly affected by the fluid (Ko et al. 2015). The force from Equation (5.4-20) is considered to be sufficiently conservative to allow the transient fluid "added mass" effect to be ignored.

The maximum impact force of a 40 ft (12.2 m) shipping container on a Risk Category III structure of 224 kips (996 kN) can be calculated using the maximum flow velocity (for Risk Category III structures) and a rigid structure impact using the elastic impact equation. Research by Piran Aghl et al. (2014) indicates a maximum force of 220 kip (980 kN) at 12.5 ft/s (3.8 m/s) which is a slightly lower velocity than the required maximum velocity for flood loading of Risk Category III structures, which is in line with the calculated impact force.

Ships and Barges

Vessels that weigh between 2,500 lb (11.1 kN) and 88,000 lb (391 kN) are required to be considered when they are present (refer to Section 5.3.9.1.1). The vessels considered in this section are often ocean going vessels or large capacity barges greater than 30 ft (9.1 m) in length.

When a structural element cannot be economically designed for the forces required by the debris impact, it is permissible to let that structural element fail and use a progressive collapse analysis to show the structure will not collapse. This approach is allowed for the medium-large debris types (ships/barges and shipping containers) to reduce the design effects of a debris strike. The

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common coastal construction type on the Gulf and East Coast is an elevated structure supported by a large number of wood piles (often diameter of 12 to 16 in.) and small spacing. These piles often have a very limited lateral capacity limited by geotechnical considerations and it would not be feasible to design these piles for debris strikes. As an economic compromise the exception allows these piles to fail and a transfer beam to be designed considering the failure of a pile below to transfer the load.

The exception considers the typical construction type of wood piles supporting an elevated structure on the Gulf and East Coast. These types of wood piles have minimal lateral capacity in soil and may not be able to resist larger impact forces individually. As a tradeoff, these piles may fail individually, and progressive collapse provisions may be used to evaluate the surrounding structure. Piles of other materials, such as steel and concrete, may also have limited individual lateral capacity dependent on the geotechnical conditions in which they are installed.

C5.4.5.3 Extraordinary Debris Impact

Extraordinary debris impacts, defined as impact by 88,000 lb (391 kN) or larger marine vessels, should be considered for Risk Category IV buildings and structures that are in the debris hazard impact region of a port or harbor, as defined in Section 5.3.9.1.2 and for which the design flood depth is 12 ft (3.7 m) or larger.

The size vessel to be used depends on the most probable size vessel typically present at the port or harbor. The harbormaster or port authority can be consulted to determine typical vessel sizes, ballasted drafts, and weight displacement under ballasted draft. Typical vessel sizes are also provided in PIANC (2014).

The nominal impact force is calculated with Equation (5.4-20), with the assumption that the vessel stiffness is much larger than the structural member stiffness, thus the transverse structural member stiffness is to be used. The calculated force may be larger than any economical capacity of typical structural elements. In that case the member may be assumed to have failed, in which case progressive collapse should be prevented for these important structures. The provisions require that progressive collapse be checked at all levels where the extraordinary debris strike could occur (with large ships this could be well above the Design Stillwater Flood Elevation).

C5.4.5.4 Debris Impact Load Redistribution

When it is not practical to design an element to take the large forces (often a shipping container, large ship or barge), the use of progressive collapse prevention is an alternative to mitigate the debris strike. An accepted procedure for designing for progressive collapse is the ‘alternate load path’ procedure given by *Design of Structures to Resist Progressive Collapse* (DOD 2013). This procedure requires the structural system to be able to carry the gravity loads of the building while sustaining a loss of a vertical load carrying element. All gravity load carrying elements that are required to sustain debris strikes need to be independently considered as lost for this analysis.

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C5.5 FLOOD LOAD CASES

The effects of different flood loading conditions can often occur simultaneously. As a result, Section 5.5 requires several flood load cases to be considered in combination as the flood load effect (F_a) that is combined with other forces in Chapter 2.

Cases 1 and 2 are required for analysis of both individual elements (e.g., columns or facades) and the load-resisting systems (i.e., gravity system and lateral system). Structures allowing passage of flood water through unenclosed spaces (e.g., building perimeter not enclosed by cladding or foundations walls) supported on columns, walls, or piles will not experience wave loads on all exposed foundation elements simultaneously. A more accurate representation of wave load behaviors for the stability of the structure would be to apply wave loads to a single row of columns (i.e., the front row), acting concurrently with hydrodynamic drag load applied to all the other rows of columns. In many cases, the effective hydrostatic load is zero as the load is uniform on all faces of the element and cancels out.

C5.5.1 Stability Against Uplift

Structures must be designed to resist flotation due to upward hydrostatic buoyancy. However, since this is a stability check, it is governed by flood load factors that are different from those of Chapter 2. In general, an uplift failure produces a temporary lifting of a structure as a whole, or portion thereof.

The calculation for resistance to uplift in Equation (5.5-1) uses a load factor of 0.9 for dead load where only the self-weight component of the total dead load is included for this stability check. The 0.9 self-weight load factor differs from the 0.6 dead load factor typical in Chapter 2 ASD load combinations, which are traditionally used for stability checks under other load sources, such as wind uplift. This larger load factor allows for a greater percentage of the actual dead load expected to be present during a flood event to be used for resistance to buoyant uplift while simultaneously disallowing consideration of superimposed loads that may not be present during an uplift event. The supplemental resistance term is intended to capture piles or other foundation elements with tension capacity if properly developed throughout the structural frame. Resistance can be found from side friction of embedded below grade elements as they attempt to lift. Resistance may also be provided by overburden that will remain in place over shallow foundation elements during flood events. Appropriate conservatism should be accounted for in the geotechnical parameters for the flooded condition. If supplemental uplift resistance from these additional elements is being taken into consideration, the engineer should ensure that the connections from these elements to the structure are capable of transmitting the tensile load, and that the load path from the point of buoyant load application to the point of uplift resistance is complete and designed accordingly. All individual elements that are part of the complete uplift resistance load path should be checked with their appropriate material-specific factors of safety.

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It is important to evaluate uplift resistance on the overall structure and also at portions of the overall structure with non-uniform self-weight or uplift resistance, and the interface between these different portions of the overall structure. For instance, if a multi-story structure has a one-story extension with an integral basement, the effects of buoyancy should be evaluated on the entire structure considering the differing self-weight and uplift resistances and check the interface for differential shear, bending, and displacement to assure proper performance.

The 0.6 factor on the wind uplift load in this stability check is intended to convert the wind load from strength design levels to allowable stress design levels.

C5.5.2 Stability Against Sliding

Similar to evaluating stability against uplift, the load factors in Chapter 2 must be modified to evaluate sliding stability. Since sliding resistance of structures typically relies on dead weight to engage friction at the base of foundations, buoyancy effects can severely impact the normal force and corresponding sliding resistance. This reduction in the net downward force used to determine frictional resistance shall include reduction due to buoyancy as indicated in the load combinations provided. Frictional sliding coefficients on soils vary depending on the roughness between interfacing materials, (e.g., concrete and steel will have different coefficients on sands) and vary in general depending on the soil gradation. Multiple sources exist for sliding coefficient estimates and should be selected at the discretion of the designer. One available resource for sliding friction coefficients is NAVFAC (1986), though it is specific to retaining walls. The designer should also consider the potential for preferential slip planes, such as smooth geotextiles placed at subgrade or weak seams of soil beneath bearing strata, which may dictate the sliding stability of the structure. Effects of these slip planes can be evaluated through a geotechnical slope stability analysis that appropriately models shear strength parameters at these planes.

The term F_{BR} that is calculated for evaluating buoyancy resistance is used in Equation (5.5-2) for consistency in the treatment of dead weight in a flooded state. Additional resistance to sliding may be achieved by passive earth pressures parallel to direction being analyzed and friction on the sides of structures parallel to the direction being analyzed. Supplemental permanent or temporary structural bracing elements may also be counted upon for resistance if the designer knows they will remain in place and be activated during the design flood event. The designer should be aware that if passive soil pressures are relied upon for sliding resistance, the structure may be expected to slide slightly to mobilize passive forces.

Sliding stability as it is discussed in this section is specific to conditions expected during a flood event, which will differ depending on the type of flooding experienced. Coastal flooding is typically caused by storm surge events that can be accompanied by strong winds. Riverine or lake flooding are not necessarily associated with high wind speed events. The designer should also be aware that lateral resistance derived from different sources such as piles, sliding friction,

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passive resistance, and structural bracing all mobilize at different strains. The effects of soil-structure interaction should be evaluated by a geotechnical engineer to provide the desired performance of the building.

The 0.6 factors on the wind uplift and lateral loads in this stability check are intended to convert the wind load from strength design levels to allowable stress design levels.

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REFERENCES:

AASHTO (American Association of State Highway and Transportation Officials). 2008. *Guide specifications for bridges vulnerable to coastal storms*. Washington, DC: AASHTO.

ASCE. 2017. *Seismic evaluation and retrofit of existing buildings*, ASCE 41-17. Reston, VA: ASCE.

ASCE. 2014. *Flood resistant design and construction*, ASCE 24-14. Reston, VA: ASCE.

ATC (Applied Technology Council). 2004. Field manual: Safety evaluation of buildings after windstorms and floods, ATC-45. Redwood City, CA: ATC.

AWC (American Wood Council. 2018. *National design specification for wood construction*. Leesburg, VA: AWC.

Ayyub, B.M. (ed.). 2018. *Climate-resilient infrastructure: Adaptive design and risk management*, MOP 140. Reston, VA: ASCE.

Bea, R. G., T. Xu, J. Stear, and R. Ramos. 1999. "Wave forces on decks of offshore platforms." *J. Waterw. Port Coast. Ocean Eng*. 125 (3): 136–144.

Bradner, C., T. Schumacher, D. Cox, and C. Higgins. 2011. "Experimental setup for a large-scale bridge superstructure model subjected to waves" *J. Waterw. Port Coast. Ocean Eng*. 137 (1): 3–11.

Cialone, M. A., T. C. Massey, M. E. Anderson, A. S. Grzegorzewski, et al. 2015. "North Atlantic Coast comprehensive study (NACCS) coastal storm model simulations: Waves and water levels." *ERDC/CHL TR-15-14*. Vicksburg, MS: US Army Engineering Research and Development Center.

Clough, R. W., and J. Penzien. 1993. *Dynamics of structures*, 2nd Ed. New York: McGraw-Hill.

Cuomo, G., M. Tirindelli, and W. Allsop. 2007. "Wave-in-deck loads on exposed jetties." *Coast. Eng*. 54 (2007): 657–679.

DOD (Department of Defense). 2013. "Design of structures to resist progressive collapse," *UFC 4-023-03*. July 2009, including Change 2-June 2013. Washington, DC: DOD.

Dershum, C., I. Nistor, J. Stolle, and N. Goseberg. 2018. “Debris impact under extreme hydrodynamic conditions. Part 1: Hydrodynamics and impact geometry.” *Coast. Eng*. 141: 224–235.

Douglass, S.L., Q. Chen, J. M. Olsen, B. L. Edge, et al. 2006. *Wave forces on bridge decks.* Mobile, AL: University of South Alabama, Coastal Transportation Engineering Research and Education Center.

East, J. W., M. J. Turco, and R. R. Mason Jr. 2008. “Monitoring inland storm surge and flooding from Hurricane Ike in Texas and Louisiana, September 2008.” *Open-file Rep. USGS 2008-1365*. Reston, VA: US Geological Survey.

FEMA (Federal Emergency Management Agency). 2020. “Free-of-obstruction requirements for buildings located in coastal high hazard areas in accordance with the National Flood Insurance Program.” *Tech. Bull.* 5. Mitigation Directorate. Washington, DC: FEMA.

FEMA. 2021. “Design and construction guidance for breakaway walls below elevated coastal buildings in accordance with the National Flood Insurance Program.” *Tech. Bull. 9.* Mitigation Directorate. Washington, DC: FEMA.

FEMA. 2020. National flood insurance program, *44 CFR, Ch. 1, Parts 59 and 60*, Washington, DC.: FEMA.

FEMA. 2011. *Coastal construction manual*, *P-55*. 4th Ed. Washington, DC: FEMA.

FEMA. 2006. “Hurricane Katrina in the Gulf Coast, Building performance observations, recommendations, and technical guidance.” Mitigation Assessment Team Report Washington, DC: FEMA, Mitigation Assessment Team.

FHWA (Federal Highway Administration. 2012. “Evaluating scour at bridges, hydraulic engineering.” *Circular No. 18. Publication No. FHWA-HIF-12-003*. Washington, DC: FHWA.

Goda, Y. 1974. “New wave pressure formulae for composite breakwater,” In *Proc., 14th Conf. on Coastal Engineering*, Copenhagen. Reston, VA: ASCE, 1702–1720.

Goda, Y. 2010. “Random seas and design of maritime structures.” *In* Advanced series on oceanic engineering, 3rd Ed. Vol. 33. https://doi.org/10.1142/7425.

Haehnel, R., and S. Daly. 2001. “Debris impact tests.” *Tech. Rep.* Hanover, NH:US Army Cold Regions Research and Engineering Laboratory.

ICC (International Code Council). 2021. *Performance code for buildings and facilities*. Country Club Hills, IL: ICC.

Kaplan, P., J. J. Murray, and W. C. Yu. 1995.“Theoretical analysis of wave impact forces on platform deck structures.” *Offshore Tech. OMAE, Vol. 1 A*. New York: ASME, 189–198.

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Kennedy, A., A. Copp, M. Florence, A. Gradel, et al. 2020. “Hurricane Michael in the area of Mexico Beach, Florida.” *J. Waterw. Port Coast. Ocean Eng*. DOI: 10.1061/(ASCE)WW.1943-5460.0000590.

Kriebel, D., L. Buss, and S. Rogers, S.2000. “Impact loads from flood borne debris.” *Tech Rep.* Reston, VA.: ASCE.

Ko H., D. T. Cox, H. R. Riggs, and C. Naito. 2015. “Hydraulic experiments on impact forces from tsunami-driven debris,” *J. Waterw., Port Coast. Ocean Eng.* 141: 3. DOI: 10.1061/(ASCE)WW.1943-5460.0000286.

Melby, J. A., T. C. Massey, A. L. Stehno, N. C. Nadal-Caraballo, et al. 2020. “Sabine Pass to Galveston Bay, TX, pre-construction, engineering and design (PED) hurricane coastal storm surge and wave hazard assessment: Report 1- Background and approach.” *ERDC/CHL Tech. Rep*. Vicksburg, MS: US Army Engineer Research and Development Center.

Nadal-Caraballo, N. C., J. A. Melby, V. M. Gonzalez, and A. T. Cox. 2015. “Coastal storm hazards from Virginia to Maine.” *Tech.Rep.ERDC/CHL TR-15-5*. Vicksburg, MS: US Army Engineer Research and Development Center.

NAS (National Academy of Sciences). 1977 “Methodology for calculating wave action effects associated with storm surges.” Washington, DC: NAS.

NAVFAC (Naval Facilities Engineering Command). 1986. “Design manual 7.02 – Foundations and earth structures.” Alexandria, VA: NAVFAC.

NIST (National Institute of Standards and Testing). 2018, “Research needs to support immediate occupancy building performance objective following natural hazard events.” *Special Publication 1224*. Gaithersburg, MD: NIST.

Park, H., T. Tomiczek, D. T. Cox, J. W. van de Lindt, et al. 2017. “Experimental modeling of horizontal and vertical wave forces on an elevated coastal structure.” *Coast. Eng*. 128: 58-74.

Piran Aghl, P., C. J. Naito, and H. R. Riggs. 2014. “Full-scale experimental study of impact demands resulting from high mass, low velocity debris.” *J. Struct. Eng.* 140: 5. DOI: 10.1061/(ASCE)ST.1943-541X.0000948, 04014006.

Shafiei, S., B. W. Melville, A. Y. Shamseldin, K. N. Adams, et al. 2016. “Experimental investigation of tsunami-borne debris impact force on structures: Factors affecting impulse-momentum formula.” *Ocean Eng.* 127: 158–169.

Suchithra, N., and P. M. Koola. 1995. “A study of wave impact on horizontal slabs,” *Ocean Eng*. 22 (7): 687–697.

Takahashi, S., K. Tanimoto, and K. Simosako. 1994. “A proposal of impulsive pressure coefficient for the design of composite breakwaters,” In. *Proc., Int. Conf. Hydro-Technical Eng. for Port and Harbor Constr. (Hydro-Port 94)*, Yokosuka, Japan, 489–504.

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Tomiczek, T., A. Kennedy, and S. Rodgers. 2014. “Collapse limit state fragilities of wood-frame residences from storm surge and waves during Hurricane Ike.” *J. Waterw. Port Coast. Ocean Eng.* 140 (1), 43–55.

Tomiczek, T., A. Wyman, H. Park, and D. T. Cox.2019. “Modified Goda equations to predict pressure distribution and horizontal forces for design of elevated coastal structures.” *J. Waterw. Port Coast. Ocean Eng*. 145: 6.

USACE (US Army Corps of Engineers). 1995. “Flood proofing regulations.” *EP 1165-2-314*. Washington, DC: USACE, Office of the Chief of Engineers.

USACE. 2002. *Coastal engineering manual*. Washington, DC: USACE, Coastal Hydraulics Laboratory, Waterways Experiment Station.

Venugopal, V., K. S. Varyani, and N. D. P. Barltrop. 2006. “Wave force coefficients for horizontally submerged rectangular cylinders.” *Ocean Eng*. 33 (11-12):1669–1704.

Walton, T. L. Jr., J. P. Ahrens, C. L. Truitt, and R. G. Dean.1989. “Criteria for evaluating coastal flood protection structures.” *Tech. Rep. CERC 89-15*. Vicksburg, MS: US Army Corps of Engineers Waterways Experiment Station.

Wang, H. 1970. “Water wave pressure on horizontal plate.” *J. Hydraul. Div*. 96 (10): 1997–2016.

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CODES AND STANDARDS

Major Changes to ASCE 7-22 Flood Loads

The changes to flood design should significantly strengthen the flood load resistance for structures designed to these new provisions. By William L. Coulbourne, PE; Daniel Cox, Ph.D; and Jessica Mandrick, PE, SE

August 1, 2024

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ASCE 7-22 Minimum Design Loads and Associated Criteria for Buildings and Other Structures Supplement 2 was published in May 2023 and incorporates a complete

revision of the flood load provisions of the standard. Prior to the supplement, the flood load provisions that are part of ASCE 7 Chapter 5, had been minimally changed since 1998. In contrast, communities in coastal and riverine areas have experienced extensive damage and loss from extreme storms with nine of the 10 costliest Atlantic hurricane seasons occurring since 2004. As a result, many jurisdictions have sought to increase flood standards locally. Figure 1 shows severe damage to two recently constructed houses, both of which were damaged from Hurricane Michael in 2018 when both were outside the 100-year floodplain. Building to the new flood provisions would have either made these houses more robust or they would have been elevated to minimize flood damage. With many lessons learned and new research conducted since 1998, the ASCE 7-22 Flood Load Subcommittee strongly felt that the standard needed to be replaced with up-to-date formulas and methods. The subcommittee developed a new approach for addressing the reliability of building design for flood considering climate change effects, particularly sea level rise. All references in this article to ASCE 7-22 flood loads are to Supplement 2.

The current design requirements in ASCE 7-16 for flood elevation only required designs to the 100-year flood (the 1% annual chance flood) plus some amount of freeboard. The use of the 100-year flood was largely based on the National Flood Insurance Program (NFIP) Base Flood Elevation (BFE) and did not meet the reliability targets of ASCE 7. This freeboard added to the Base Flood Elevation was a fixed amount based of the requirements of NFIP, ASCE 24, or the local jurisdictions; it was not risk-based and had no particular connection to the importance of the facility to the community. Dependent upon site conditions such as the topography and presence of waves, the freeboard provided inconsistent levels of protection above the 100-year flood. Moreover, ASCE 7-16 applied only to structures located within the 100-year flood area. Even as some attempts were made to increase elevation requirements via freeboard, none of this applied to structures immediately adjacent to the 100-year flood area, creating a ‘waterfall’ effect.

ASCE 7-16 and earlier editions recognized that the 100-year flood load did not meet the reliability targets of the standard and assigned a load factor of 2.0 to coastal A and V zones in an attempt to increase the reliability. This presented a similar issue to the addition of freeboard. The load factor of 2.0 scaled the magnitude of the horizontal flood force but did not scale the elevation of the flood water. The Flood Load Subcommittee wanted flood design to be based on risk and to be risk consistent across the country.

A Change in Definition

One of the most significant changes in ASCE 7-22 Supplement 2 is the change in the definition of the flood hazard area. Previously, structures within the 100-year flood area, or the Special Flood Hazard Area in the terminology of flood plain management, were subjected to ASCE 7. However, the new definition calls for the 500-year floodplain to be the new area of applicability for Risk Categories II, III, and IV structures. For Risk Category I structures, the 100-year floodplain remains as the designated flood hazard area. This change has significant implications for all new construction and substantial

improvements to structures lying between the maximum extents of the 100-year and the 500-year flood areas.

The new approach can be described as going beyond the National Flood Insurance Program regulations and requirements. The new flood load provisions do not tie the loads to a fixed regulatory elevation but instead use a risk-based approach to determine the flood hazard and then use the hazard levels to calculate the loads for the selected flood hazard. The new definition in the revised standard for the design flood is "The flood corresponding to the design mean recurrence interval assigned by risk category in accordance with Table 5.3-1, including relative sea level change." This revised definition includes references to two major changes in the ASCE 7-22 provisions. One is the link between flood design, flood return periods, and building risk category. The second is the inclusion of relative sea level change as part of the design flood. A reduced version of Table 5.3-1 is shown in Table 1.

The Flood Hazard

The revised ASCE 7 Flood Load chapter now requires the use of a return period for design based on the Risk Category that ASCE uses to define use and occupancy classes. As evidenced by the amount of flood damage, losses, and claims in areas beyond the special flood hazard area, as shown in Figure 1, the regulatory minimum elevation that uses the 100-year event is no longer sufficient to reduce losses caused by flooding.

The solution to the problems of under-estimating the flood hazard and improving risk consistency is to require flood designs for each Risk Category to a specified flood return period. The risk categories and their corresponding mean recurrence intervals are shown in Table 1.
The advantage of using this method is that most buildings fall into Risk Category II and federally published Flood Insurance Studies (FIS) typically have 500-year flood elevation data in addition to the 100-year data and many FEMA Flood Insurance Rates Maps (FIRMs) also delineate the extent of the 500-year flood plain. The disadvantage of this method is that the 750- and 1000-year MRI elevations and flood conditions are typically not published in the FIS or on the FIRM. In order to determine these larger return period floods, scaling factors were developed for both riverine and coastal conditions to convert the 100-year flood elevation to the desired mean recurrence interval. The table of scaling factors is shown as Table 2. These scaling factors are also part of the standard Table 5.3-1.

The amount of flood information available from federally published flood studies varies depending on the amount and type of information collected and developed regarding the local floodplain and the date of the study. Table 2 assumes that 100-year flood elevation data is available and thus can be used to scale from. The revised standard addresses the issue of unavailable data, so the user knows how to proceed to obtain the required design flood elevation.

Flood velocity and wave heights are also part of the flood hazard. Scaling factors are also provided for those parameters for return periods greater than 100 years. These are shown in Table 3 and are in the standard as Tables 5.3-2 (velocity) and 5.3-3 (wave height).

These changes now require the user to select the Risk Category, determine the flood hazard level and calculate flood loads based on the design flood depth. In many instances, especially coastal, the designer may elect to elevate the building above the expected flood level instead of fortifying the building sufficiently to 'resist' the flood.

Another significant change is the inclusion of climate change effects in the determination of the design flood. The ASCE 7-22 equation for design stillwater flood depth is: df = (Stillwater elevation for design MRI—Ground elevation including effects of erosion) + Δ sea level rise.
The revised standard now requires that climate change in coastal flood plains be considered by adding the change in sea level rise to the flood depth. The user is to consider the SLR effect over a 50-year period, the minimum of this change effect is to be a straight-line extrapolation of the historical SLR. Other more conservative approaches may be used including projections made by the U.S. Army Corps of Engineers (USACE) a link to the Corps projections is provided in the standard. The Corps data makes projections for a low, intermediate or high rate of SLR until the year 2100. Those projections allow the user to make a choice of which rate is the most appropriate for their design condition or which rate best suits the needs of the client.

The new chapter also includes guidance on the amount of scour to consider for columns and walls under breaking and nonbreaking wave conditions.

Flood Load Formula Changes

There are changes to several flood load formulas in addition to the changes made in defining the flood hazard.

1. Flood velocity has been reduced to: $V = Cv\sqrt{gdf}$, where Cv is a velocity coefficient taken as 0.5, g is acceleration due to gravity, and df is the design stillwater flood depth. This change was made based on extensive study by the USACE on velocity of coastal floods; the method previously used in ASCE 7 was thought to be very conservative and the recent Corps study has confirmed that thought. Figure 2 illustrates the results of the velocity study data points in comparison to ASCE7-22 and ASCE 7-16 formulas.
2. Calculation of wave loads was changed to follow the Goda method. This method depends on adjusting the wave load effect on a building with the height of the wave and the depth of the building in relation to the still water level. Wave wash up on a wall is also considered if the wall is located such that the wash up effect can occur. Figure 3 is one of the new wave conditions showing the bottom of a building partially submerged below the stillwater level. The Goda equations allow the determination of the pressure profile acting on the building, as opposed to the

previous breaking wave formula which was applied as a concentrated force at the stillwater elevation.

3. Flood-borne debris design criteria has been added; the provisions and methods are patterned after those used in Chapter 6 on Tsunami loads. Risk Category I structures are exempt from the debris design criteria, as are one- and two-family dwellings, and Risk Category II buildings outside of the special flood hazard area. The chapter specifies the types of debris and their properties (threshold depth, mass, stiffness) to be considered for each risk category. Engineers should note that for a debris impact, the stiffness of the impacted structural element (weak axis bending stiffness of a wall or bending stiffness of a column) may often be considerably less than the axial debris stiffness. Considering the stiffness of the impacted object, as permitted by the standard can significantly reduce the debris impact load.
4. A method has been added to be able to determine if the site is subject to either non-breaking or breaking waves. The difference in wave loads from these two conditions can be significant.
5. Load combinations for various flood conditions have been determined so that the total flood load is used in the application of the appropriate load combination from ASCE 7, Chapter 2. The combinations cover both riverine and coastal floods. For example, the flood load combination for coastal flooding is the sum of loads from hydrostatic, hydrodynamic, and waves or debris impact applied to the design element of interest. This sum is Fa in the load combination used in Chapter 2.
6. Additional provisions are included to determine if either a sliding or overturning condition might affect global stability. Both of these stability load combinations are in addition to those in Chapter 2.
7. A section has been added for Performance-based Design (PBD) for Flooding. This section points to the already permitted use of PBD in ASCE 7 and provides some guidelines on how to follow the PBD process for flooding.

The calculations for hydrostatic loads are included in the supplement, and they require that the soil be considered fully saturated unless a seepage analysis in the geotechnical report determines otherwise. The calculations for hydrodynamic load are included in the supplement and the reduction in the maximum velocity can significantly reduce the hydrodynamic pressure as the velocity term is squared in the equation. There are new provisions for determining the impact of debris damming, which is the accumulation of debris between columns of an open foundation, which results in an increased area for the application of hydrodynamic loading.

Flood Load Factor

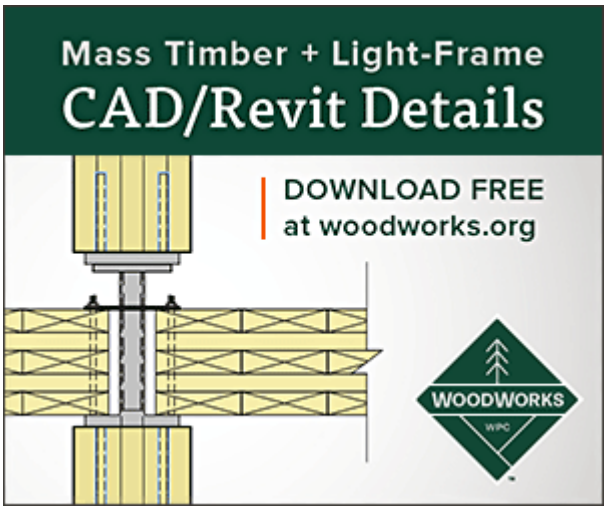
The last significant change is the reduction of load factors used in load combinations that include flood. The LRFD flood load factor has been reduced from 2.0 in V Zones and Coastal A Zones to 1.0 for all zones; the ASD load factor has been reduced from 1.5 in V Zones and Coastal A Zones, to 0.70 for all zones. These reductions are possible because of the use of a higher return period for the design flood; the resulting loads on structural

elements now achieve the target reliabilities assigned in ASCE 7 for each of the Risk Categories.

Summary

There are a lot of changes to ASCE 7 Chapter 5, and after years of minimal changes, it will likely take some time for the practice to incorporate all these changes into their designs. The new chapter is published in ASCE 7-22 Supplement 2 and is available for free download on the ASCE website. The recently published Building Designer's Guide to Calculating Flood Loads Using ASCE 7-22 Supplement 2 by FEMA walks users through several examples and is also available for free download. FEMA continues to work on a Future of Flood Risk dataset and user tool so that in the future designers will be able to retrieve flood hazard data for various MRIs and risk probabilities. The changes to flood design that are now in ASCE 7-22, Supplement 2, should significantly strengthen the flood load resistance for structures designed to these new provisions.

William L. Coulbourne, PE, F.SEI, F.ASCE, Coulbourne Consulting, has 50 years of experience as a manager, designer, and building professional. He is a member of ASCE 7 standards committees on flood loads.
Daniel Cox, Ph.D, M.ASCE, is a professor at Oregon State University. His research focuses on community resilience to coastal hazards, including tsunami and hurricane surge and waves inundation.
Jessica Mandrick, PE, SE, M.ASCE, is Partner at Gilsanz, Murray, Steficek. She has a wide range of experience in multiple disciplines with specialties in education facilities, renovations, and buildings in the floodplain. Mandrick is also a member of the STRUCTURE magazine Editorial Board.



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FLOOD MITIGATION

ASCE 24-24 Delivers Major Update to Flood Resistant Design Standards

By **News Editor** March 17, 2025

A new national standard could significantly change how communities mitigate flooding. The American Society of Civil Engineers (ASCE) has released **Flood Resistant Design and Construction, ASCE/SEI 24-24** an update to its widely used standards for structures in flood hazard areas.

The 2024 edition provides minimum requirements for flood resistant design and construction of structures that are subject to building code requirements, floodplain management regulations, or other requirements that cite this standa ASCE 24-24 contains significant changes from the previous version, ASCE 24-14 and aligns with the ASCE 7-22 Supplement 2 for design flood loads, which was released in May 2023.

“This may be the most significant upgrade in the nation’s flood loss reduction standards since the creation of the NFIP minimums in 1973, and it could not come at a better time as annual flood losses in the country now average more than $45 billion/year,” said **Chad Berginnis**, **CFM**, Executive Director of ASFPM.

Among numerous provisions contained in this standard, four primary updates stand out:

1. **Expanded flood hazard area.** The flood hazard area is redefined to include the 500-year floodplain (where it is mapped as Shaded X Zone or Zone B or C on some older FIRMs) as well as the 100-year floodplain (SFHA).

2. **Elevation requirements are tied to the flood design class of the structure**. The assignment of the flood design class is based on a building or structure's risk to human life, health and welfare if affected by flooding. For most residential, commercial, and industrial structures, this is the 500-year mean recurrence interval (MRI) flood event. For more important facilities, it is either the 750-year (buildings and structures that pose a high risk to the public or significant disruption to community) or 1,000-year (buildings and structure that contain essential facilities and services necessary for emergency respo and recovery) MRI flood event. Only certain accessory and agricultural structures would be allowed at the 100-year MRI flood elevation.

3. **Climate change considerations**. Coastal floodplain calculations must now factor in future sea level change based on historic trends.

4. **Enhanced dry floodproofing requirements.** The standard overhauls requirements for dry floodproofing, including the required use of ANSI/FM 2510- certified products and updates to inspection and maintenance needs and flood emergency operation plans.

How Model Codes and Standards are Developed

ASCE 24-24 was developed by the Flood Resistant Design and Construction Standards Committee of the Structural Engineering Institute of ASCE. Model codes and standards are developed by experienced volunteer professionals working together through a multi-step, consensus-based process. Often, provisions start as case study reports or research papers before evolving into guidelines, then standards, and finally incorporation into model codes.

ASCE, as a premier American National Standards Institute (ANSI)-approved standards organization, develops and maintains many of the standards referenced or incorporated in the model building codes. Through a thoughtful and extensive process, ASCE assures that each standard represents a broad consensus of the related professional community. The standards developed by the U.S. voluntary consensus standards system empower our nation domestically and globally.

"The primary objectives of the ASCE 24-24 Committee were to align the requirements in ASCE 24 with ASCE 7-22 Supplement 2 and update the standar to incorporate insights gained since it was last updated 10 years ago," said **Manny Perotin,** co-chair of ASFPM's Nonstructural Floodproofing Committee a one of the volunteers who served as an associate member on the committee th helped develop the standard. "While there is nothing foolproof about wet or dr floodproofing, the updates to this standard help communities and design professionals construct buildings that are more flood resistant. I encourage federal, state, and local officials to consider incorporating these requirements along with other best practices like proper planning and zoning, continuing to advance their flood hazard data, and delivering training to help properly adopt and enforce these new requirements to help continue reducing flood property damage."

"One factor we haven't understood well is how much protection one or two feet of freeboard supplies," said **Dr. Carol Friedland**, ASCE 24 committee member and director of the LaHouse Research and Education Center at the Louisiana State University (LSU) AgCenter. "Through the process of updating the ASCE 24 standard, we found that a fixed freeboard amount provides variable protection depending on the location. Moving to a return period or probability basis protects everyone to the same level, regardless of where they are in the country. This is a significant improvement over previous flood protection approaches."

What's Next?

The International Code Council (ICC) produces a series of model codes known as the I-Codes. The most recent editions — the 2024 I-Codes — are due for an update in 2027 and that process has already begun. ASCE 7 and ASCE 24 have long been the reference standards related to flooding in the I-Codes. As such, proposals are already being developed to have ASCE 24-24 be considered for 2027 I-Codes update.

But there's no reason to wait for the building codes.

"Over 22,000 communities participate in the NFIP and as such have adopted floodplain management regulations," said Berginnis. "Why not adopt the releva sections of ASCE 24-24 directly into a community's floodplain management standards?"

Steps to Facilitate Adoption

ASFPM is taking action to make it easier for communities to adopt ASCE 24-24 including:

- **Raise awareness of the standard**. ASFPM's Non-Structural Floodproofing Committee is working on a webinar to introduce the standard to our members. Additionally, the association is developing a workshop for the

ASFPM Annual Conference and will make additional training materials available.

- **Facilitate easy access to and use of the standard.** ASFPM is trying to reduce barriers accessing the standard and is working with ASCE to develop solutions. The LSU AgCenter has developed an easy-to-use, **web-based calculator** to determine the required elevations for different flood design classes based on the new ASCE 24-24 requirements.
- **Update ASFPM's model higher standards guide** to include language to facilitate adoption of the ASCE 24-24 requirements into floodplain management standards.
- **Engage with states.** ASFPM is working with states to become more familiar with the standard and to potentially incorporate it into a state's model ordinance as a suggested higher standard.

"The beauty of having a national consensus standard is that it didn't come from the government and it can't be taken away by the government," said Berginnis. is what the practitioner community says is needed to reduce flood losses in the nation. Whether it is used to backstop states and communities that already hav higher standards like a 2 foot freeboard or gives the impetus needed to adopt a higher standard, we cannot continue to do things like we have been doing, floo losses are increasing far too fast."

To learn more about the standard or obtain a copy, **visit the ASCE library**.

#ASCE 24-24 **#Dry Floodproofing** **#Flood Mitigation** **#flood standards**

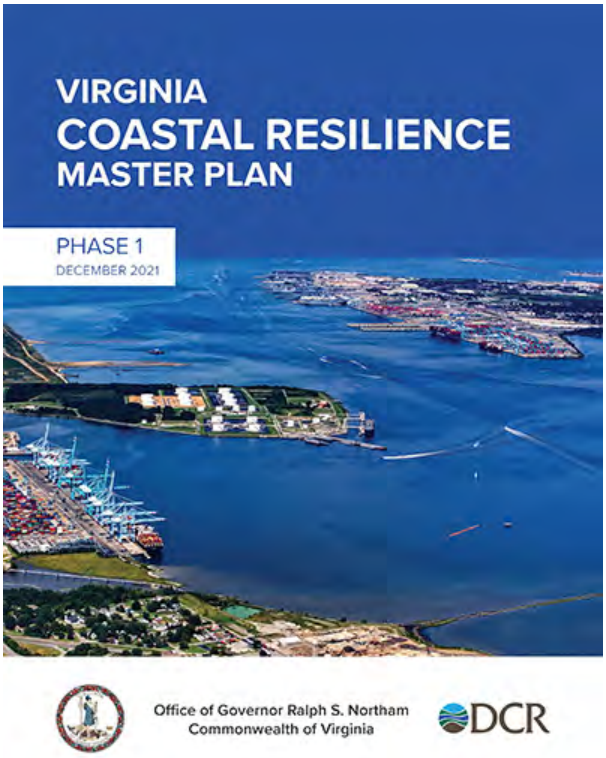
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Department of Conservation and Recreation

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Virginia Coastal Resilience Master Plan

Phase One, December 2021



The Commonwealth of Virginia released The Virginia Coastal Resilience Master Plan (CRMP) Phase I in December 2021.

This first phase of Virginia Coastal Resilience Master Plan is a call to action for the Commonwealth. From growing cities to migrating coastal wetlands, Virginia's coast faces a new reality. This Plan shows that without action, rising sea levels and increasingly severe weather from climate change threaten our cherished coastal regions' economic, cultural, and environmental resources.

The Master Plan builds on the 2020 Virginia Coastal Resilience Master Planning Framework, which outlined the goals and principles of the Commonwealth's statewide coastal resilience strategy. Recognizing the urgent challenge flooding already poses, the Commonwealth developed Phase One of the Master Plan on an accelerated timeline and focused this first assessment on the impacts of tidal and storm surge coastal flooding on coastal Virginia.

Download the Master Plan document

What We've Done +

What We Learned +

What We're Doing About It +

What's Next +

The Master Plan Document +

Presentations +

Virginia Department of Conservation and Recreation
600 East Main Street, 24th floor | Richmond, VA 23219-2094 | 804-786-6124

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B3500-24 – Staff Summary

Proponent: Mark Dreyer, Commonwealth of Virginia - Department of General Services, representing Division of Engineering and Buildings.

Brief Description: Requires buildings to comply with ASCE/SEI 24-2024 (2021 VCC and 2024 IBC reference ASCE/SEI 24-2014), and with ASCE/SEI 7-22 including Supplements 1 and 2 (2021 VCC and 2024 IBC reference ASCE/SEI 7-22 without Supplements 1 and 2).

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Second GSW Meeting — 10/03/2025

Support: None

Opposition: Steve Shapiro, Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA); Dan Willham, Fairfax County and Virginia Building and Code Officials Association (VBCOA); and Andrew Clack, Home Builders Association of Virginia (HBAV).

Discussion:

Jeff Brown (DHCD staff) provided an overview of the proposal.

a. **Steve S** noted that this proposal goes beyond what ICC did with regard to ASCE supplement 2, further stating that the cost is enormous, especially considering those buildings constructed in flood hazard areas.
b. **Dan W** and **Andrew C** opposed for the same reasons noted by **Steve S**.

DHCD Staff Note: N/A

RB301.2.1-24

VRC: R301.2.1

Proponents: Chase McArthur, representing Turnkey Porch Enclosures

2021 Virginia Residential Code

Revise as follows:

R301.2.1 Wind design criteria. Buildings and portions thereof shall be constructed in accordance with the wind provisions of this code using the ultimate design wind speed in Table R301.2 as determined from Figure R301.2(2). The structural provisions of this code for wind loads are not permitted where wind design is required as specified in Section R301.2.1.1. Where different construction methods and structural materials are used for various portions of a building, the applicable requirements of this section for each portion shall apply. Where not otherwise specified, the wind loads listed in Table R301.2.1(1) adjusted for height and exposure using Table R301.2.1(2) shall be used to determine design load performance requirements for wall coverings, curtain walls, roof coverings, exterior windows, skylights, garage doors and exterior doors. Asphalt shingles shall be designed for wind speeds in accordance with Section R905.2.4. *Metal roof shingles* shall be designed for wind speeds in accordance with Section R905.4.4 . A continuous load path shall be provided to transmit the applicable uplift forces in Section R802.11 from the *roof assembly* to the foundation. Where ultimate design wind speeds in Figure R301.2(2) are less than the lowest wind speed indicated in the prescriptive provisions of this code, the lowest wind speed indicated in the prescriptive provisions of this code shall be used.

Wind speeds for localities in special wind regions, near mountainous terrain, and near gorges shall be based on elevation. Areas at 4,000 feet (1219 m) in elevation or higher shall use the ultimate design wind speed of 140 mph (62.6 m/s) and areas lower than 4,000 feet (1219 m) in elevation shall use the ultimate design wind speed of 110 mph (49.2 m/s). Gorge areas shall be based on the highest recorded speed per locality or in accordance with local jurisdiction requirements determined in accordance with Section 26.5.2 of ASCE 7 .

Exception: Openings for exterior balconies, decks, or porches under roofs enclosed with screen or removable vinyl or acrylic wind break panels shall be exempt from the loads listed in Table R301.2.1(1) and the height and exposure factors listed in Table R301.2.1(2). Vinyl and acrylic glazed panels shall be removable. Removable panels shall be identified as removable by a decal. The identification decal shall state “Removable panel SHALL be removed when wind speeds exceed 75 mph (34 m/s).” Decals shall be placed such that the decal is visible when the panel is installed.

Reason Statement: This amendment proposes an exception under Section R301.2.1 of the 2021 Virginia Residential Code, consistent with existing provisions in North Carolina and Florida. It applies to porches, balconies, and decks with roofs enclosed by removable vinyl or acrylic panels. These enclosures, such as Turnkey’s Oasis 4-Track, are engineered to be flexible and lightweight, offering no structural resistance. Labeled for removal at wind speeds exceeding 75 mph, they revert the porch to open-air status, eliminating additional wind loads on the structure. This clarification fosters consistency across jurisdictions, reduces code ambiguity, and encourages innovation in nonhabitable porch enclosures—ensuring occupant safety without unnecessary structural demand.

Cost Impact: The code change proposal will decrease the cost

The proposal significantly reduces construction costs by preventing misclassification of removable vinyl enclosures as permanent fenestration. This avoids:

- Unnecessary lateral bracing or structural analysis
- Reinforced framing for shear loads
- Use of window-rated glazing systems

The amendment:

- Saves thousands in engineering and material expenses
- Accelerates the permitting and inspection process
- Reduces disputes and promotes code compliance

This exemption preserves the code’s intent—structural safety and clarity—while lowering the burden on outdoor living projects that

remain unconditioned and non-habitable.

Attached Files

- **VA Code Ammendment Letter.pdf**
  https://va.cdpaccess.com/proposal/1278/1795/files/download/907/

Reason Statement, Cost Impact, & Proposed Code Revision

Proposed Amendment to 2021 VRC – R301.2.1 Wind Design Criteria

Reason Statement

This amendment proposes an exception under Section R301.2.1 of the 2021 Virginia Residential Code, consistent with existing provisions in North Carolina and Florida. It applies to porches, balconies, and decks with roofs enclosed by removable vinyl or acrylic panels.

These enclosures, such as Turnkey's **Oasis 4-Track**, are engineered to be flexible and lightweight, offering no structural resistance. Labeled for removal at wind speeds exceeding 75 mph, they revert the porch to open-air status, eliminating additional wind loads on the structure.

This clarification fosters consistency across jurisdictions, reduces code ambiguity, and encourages innovation in non-habitable porch enclosures—ensuring occupant safety without unnecessary structural demand.

Statement on Construction Cost Reduction

The proposal significantly reduces construction costs by preventing misclassification of removable vinyl enclosures as permanent fenestration. This avoids:

- Unnecessary lateral bracing or structural analysis
- Reinforced framing for shear loads
- Use of window-rated glazing systems

The amendment:

- Saves thousands in engineering and material expenses
- Accelerates the permitting and inspection process
- Reduces disputes and promotes code compliance

This exemption preserves the code's intent—structural safety and clarity—while lowering the burden on outdoor living projects that remain unconditioned and non-habitable.

Proposed Code Revision (as submitted to DHCD)

SECTION R301.2.1 – WIND DESIGN CRITERIA

Exception: Openings for exterior balconies, decks, or porches under roofs enclosed with screen or removable vinyl or acrylic wind break panels shall be exempt from the loads listed in Table R301.2.1(1) and the height and exposure factors listed in Table R301.2.1(2). Vinyl and acrylic glazed panels shall be removable. Removable panels shall be identified as removable by a decal. The identification decal shall state "Removable panel SHALL be removed when wind speeds exceed 75 mph (34 m/s)." Decals shall be placed such that the decal is visible when the panel is installed.

Submitted by:
Turnkey Porch Enclosures
4109 W Clay Street, Richmond, VA 23230
chase@turnkeyporch.com (804) 567-6543

RB301.2.1-24 – Staff Summary

Proponent: Chase McArthur, representing Turnkey Porch Enclosures

Brief Description: Exempts removable vinyl or acrylic wind break panels at exterior balconies, decks, or porches under roofs from having to comply with the wind loading requirements.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

First GSW Meeting — 07/29/2025

Support: None

Opposition: D.A. Pearce, representing himself; Kyle Kratzer, Fairfax County and Virginia Building and Code Officials Association (VBCOA); and David Beahm, Warren County.

Discussion:

a. **Paul Keller** – Owner of Turnkey Porch Enclosures. Provides overview of the proposal.
   i. **Steve Shapiro** – Speaking for himself. Are there other manufacturers who make this product?
   ii. **Paul K** – There are.
   iii. **Steve S** – So this isn't unique to your product?
   iv. **Paul K** – Correct. There are similar products.
   v. **Steve S** – Not sure everybody is going to follow the instructions on a label. We are going to have windborne debris all over the place.
   vi. **Paul K** – The way we looked at this is that hurricane preparedness is universal. When there's high wind, people are moving things from their pool, securing things, and boarding up windows. This is about a 30-second way to prepare for hurricanes.

b. **D.A. Pierce** – How is this not different from a sunroom?
   i. **Paul K** – A sunroom is a glass structure. These enclosed porch areas have panels that can move and have less fixed glass than a sunroom.
   ii. **D.A. Pierce** – There are five categories of sunrooms, and this appears to fit into Category 1. All sunrooms can be built on a deck-style foundation. If it's a raised floor system, the code states that the system needs to be engineered. Would this be more appropriate in the sunroom provisions of the code, particularly under the Category 1 section? As far as engineering is concerned, you don't necessarily need a foundation; however, if you have a Category 4 or 5 sunroom, which requires insulation, there's a minimum requirement of an air barrier underneath the space if you don't have a

foundation.

iii. **Paul K** – In practically every application we are doing this, there is not a sealed or closed foundation system underneath.

c. **Kyle K** – Not opposed to a change specifically on this subject because I know this is highly debated. Did the 75-mph number strictly come from the other states, or do you have some testing that shows it fails at 75mph?
   i. **Paul K** – No. This is the verbiage that NC put in. I don't know who created that mile per hour rating.
   ii. **Steve S** – Cat 1 hurricanes start at 76mph, so this falls below this.
   iii. **Paul K** – We're trying to differentiate between a random storm and a hurricane.
   iv. **Kyle K** – Spoke with another manufacturer whose product fails at 60 mph. Is there any testing that talks about where that failure rate is?
   v. **Paul K** – I don't believe there is, but I think that is the whole reason for the labeling. Instead of being able to say definitively what this product will do, the solution is to take the sashes down once we get above these high winds.
   vi. **Kyle K** – We're already making an exception that it doesn't meet code. However, we also don't have data that states that it can meet the number we're putting on there (the 75mph figure). Not sure of anywhere else in the code where it puts the responsibility on the owner to prepare for that type of weather. This needs to be addressed; I don't know if this is the solution.

d. **Andrew Clark** [Home Builders Association of Virginia (HBAV)] – Putting the burden on the homeowner is something they may not be able to control. Would this preclude or put your company or product at a competitive advantage over others in the marketplace? Would your competitors say that they are comfortable with this?
   i. **Paul K** – It's not that you'll have a single manufacturer, I'm saying this type of product in this industry is for people who are looking for additional protection on their porch.

e. **D.A. Pierce** – A Category 1 sunroom doesn't require fenestration, just for clarification.

f. **Richard Gordon** (Hanover County) – One other consideration that we've heard is to accept this as a guard. Now we have a structural requirement it has to meet, but we're hearing it's going to blow out at 40mph or 50mph. There are more applicability situations that we need to look at, too.

g. **David B** – Opposed as it's written, particularly because of the decal language.

h. **Jeff Brown** (DHCD staff) – If we go forward with the proposal right now, it would be labeled as non-consensus. You also have the option to carry this proposal over to the next meeting to work on it and bring it back to the next workgroup meeting.
   i. **Paul K** – Is the opposition primarily if the label is permanent?
      1. D.A. Pierce – My opposition is that this is in the wrong section of the code. This should be in the Category 1 sunroom section.
   ii. **David B** – This applies to an item and an action you have to do to that item

after the fact. This seems more like a maintenance piece versus a construction piece.

iii. **Kyle K** – My opposition is that only in the event of hurricane-force winds is there cause for doing something about it, when some of these products will fail before then. I'm looking for some testing.

1. Paul K – We have a product that works well and serves a need. We're just trying to find a way to work with everybody to make this product work.

i. **Jeff B** – We can mark this as non-consensus, and it will still go to the Board for consideration with a summary of the discussion, or, if you want to get with stakeholders to work on it, we will need to table it now.

i. **Paul K** – Fine going forward as non-consensus.

DHCD Staff Note: N/A

RB324.7-24

VRC: R324.7 (New), R324.7.1 (New), Chapter 44 (New)

Proponents: William Penniman, representing Northern Virginia Bird Alliance (wpenniman@aol.com); Sonal Shah, Northern Virginia, representing Northern Virginia Bird Alliance (moiforte@gmail.com); Thomas Blackburn, Northern Virginia, representing Northern Virginia Bird Alliance (tomlblackburn@gmail.com)

2021 Virginia Residential Code

Add new text as follows:

R324.7 Bird Friendly Construction. All fenestration and other exterior glazing of new residential buildings larger than 2,500 sf above grade or supplementary structures (such as garages, sheds or greenhouses larger than 500 sf) shall use Bird-Friendly Glass as defined in section R324.7.1

R324.7.1 Definition.
Bird-Friendly Glass. Glass, other glazing materials (including spandrel glass or other transparent or highly reflective materials, such as plexiglas or polished metal) or obstructed glass that meet any of the following conditions:
1. Frosted or opaque glass or glass with exterior surface (surface1) obstructed and effectively covered by building-integrated structures that do not have gaps larger than 12-inches (12") in any dimension, including metal screens, non-glass double-skin facades, fixed solar shading, exterior in sector solar screens, grilles, child-guards and other features that meet these conditions;

2. Un-tinted glass with an outer total reflectance of ≤15% that contains a pattern of visual markers that conforms to the following rules: (i) dots or other isolated solid shapes that are ≥¼" in diameter and are either ≤ two-inches (2") apart in horizontal lines and ≤ two-inches (2") apart in vertical lines or ≤ two-inches (2") apart in any direction if randomly distributed or (ii) horizontal lines that are ≥ ⅛" in width and spaced ≤2" apart or vertical lines that are ≥⅛" in width and spaced ≤2" apart;

3. Any glazing product with a Threat Factor Rating of 30 or less as determined and published by the American Bird Conservancy. See www.birdsmartglass.org.

Revise as follows:

Chapter 44 Reference Standards. Add new standard promulgator and new standard, as follows:

ABC	American Bird Conservancy	
	P.O. Box 249, The Plains, VA 20198	

Threat Factor Rating System for bird-safe windows (https://abcbirds.org/wp-content/uploads/2025/06/What-is-a-Threat-Factor-6-9-25.pdf)

Reason Statement: This proposal is supported by Northern Virginia Bird Alliance.

Collisions with buildings kill up to 1 billion birds per year in the United States primarily due to the "invisibility" of clear glass to birds and due to reflections that appear to be attractive places to fly. https://abcbirds.org/glass-collisions/why-birds-hit-glass/This high annual loss of birds to building collisions has contributed to the significant decline that has been recorded in many bird populations during recent decades. The danger to birds exists throughout the principle "bird activity zone" up to 100 feet above grade where both local flights and migrations occur. Local flights occur throughout the year and are generally from ground to tree tops. Most collisions actually occur with glass on homes and low-rise buildings even though taller buildings, pose a greater danger on a per-building basis. https://abcbirds.org/glass-collisions/why-birds-hit-glass/ The amount of glass is the strongest predictor of birdcollisions. https://abcbirds.org/glass-collisions/architecture-planning/ Clear glass is a threat whether it is part of the building
envelope or an extension of glass above the building walls or incorporated into skyways or balconies or even smaller auxiliary structures. Bird-friendly solutions may involve building design, the glass itself (e.g., frits or printed patterns, coatings, frosting or films applied to glass) or physical structures (as simple as window screens, grills, shades or less glazing), https://abcbirds.org/glass-collisions/architecture-planning/ ("Bird

Friendly Design Guide"); https://abcbirds.org/glass-collisions/why-birds-hit-glass/ ;https://abcbirds.org/glass-collisions/photo-gallery/ ; https://www.collidescape.org/ As illustrated by the Javits Center window replacement, the use of bird-friendly glass can reduce collisions by over 90%.https://abcbirds.org/glass- collisions/architecture-planning/

The range of bird-friendly glazing and design is growing as architects, builders and glass companies make concerted efforts to minimize building threats to birds. https://abcbirds.org/glass-collisions/products-database/ ; https://nationalaudubon.app.box.com/s/lmf7vijbohuds6j92igzl1dzy8398ckj ; https://www.featherfriendly.com/residential ; https://www.featherfriendly.com/commercial?hsLang=en ; https://www.birdsavers.com/

A simple rule is the "2X2" standard: the 2x2 Rule is defined as a collision deterrence module based up on the physical profile of a bird in flight. Current research has established maximum module dimensions of 2" high x 2" wide. Some solutions, such as films meeting the 2X2 standard, can be applied to windows and effectively reduce collisions. The American Bird Conservancy maintains and continuously updates a list of bird-friendly materials, which can be used for compliance in order to provide flexibility for builders and architects. The ABC rates products based on the hazard they pose for birds ("ThreatFactor"). https://abcbirds.org/glass-collisions/threat-factor-rating/ The data base is available in printed form or found at https://abcbirds.org/glass-collisions/products-database/ ; www.birdsmartglass.org .

As of August 2025, there were nearly 190 bird-friendly glazing products that had been tested and found to pass the ABC's "threat" standard.

Government bodies around the country have begun to address these issues with mandatory standards for bird-friendly construction. The ABC Threat Factor Rating is based upon testing and is commonly cited (e.g.,by NYC and GSA) as a source of acceptable compliance standards.

Depending on designs and materials chosen, the solutions may be essentially invisible to occupants (e.g.,UVpatterns) or fit with the overall design pattern (e.g.,insect screens on windows) or be such (e.g.,frits) that occupants quickly get used to and see beyond the patterns.

This proposal will enhance the resiliency and survival of both local and migratory birds, which are currently killed and injured by impacts to windows and other glazing of buildings. Buildings are the second leading cause of death to birds with up to1 billion birds killed annually by striking buildings, mainly windows and other glass. The problem exists for both residential and commercial buildings, including low-rise buildings. Bird populations have declined substantially in the UnitedStates in the past 50 years, in significant part due to buildings and increased quantities of glass used in construction.

By implementing the requirements for Bird-Friendly Materials in new construction, adoption of the proposal will substantially reduce bird injuries and mortality. Experience indicates that there could be a reduction of 90% or greater with full implementation.

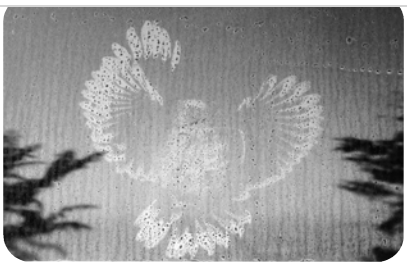
Cost Impact: The code change proposal will increase the cost

The proposed provision may, but need not, increase building costs. See https://abcbirds.org/glass-collisions/architecture-planning/ ("Bird Friendly Design Guide": "New construction can incorporate from the beginning bird-friendly design strategies that are cost neutral.").

Some approaches can raise costs of construction, since bird-friendly glass is somewhat more costly than traditional glass. However, patterns on glass are only one solution. Design decisions for new buildings can mitigate or eliminate increased costs. For example, design changes to reduce the glass areas can result in reduced constructioncosts and also save operational costs with a more efficient building envelope and lower energy consumption. The manufacturing market for bird-friendly glass and other bird-friendly solutions has become more competitive and therefore cost effective and allows designers and owners to choose from a range of options that help realize aesthetic, budget or performance goals or all of the above. In one example, construction of a building with 9,500SF of glass incurred higher building costs of "less than a fifth of a percent of total construction costs". https://livingbuilding.kendedafund.org/2019/04/26/kendeda-buildings-bird-safe-glass-shockingly-huge-issue/ . Many non-glass solutions such as films, screens, sunshades or less glass, are more economical and have other benefits. These solutions perform well on a cost-of-product and installation basis to buildings of a residential scale.

Preventing Glass Collisions

Carolina Wren at window. Photo by Kristi Blokhin, Shutterstock.



Creating a Future Without Glass Collisions

Birds see the world differently than we do — it's part of what makes them extraordinary flyers and navigators capable of migrating thousands of miles in the dark. But they aren't equipped to handle the maze of reflective windows in multi-story buildings in our cities. Nor can they see the crystal clear glass used in homes, schools, stores, and other buildings. And although these structures are shorter, they pose the same threat to birds as the skyscrapers downtown. More than 1 billion birds die from collisions with glass every year in the U.S. alone. It's a problem of a staggering scale, but it's one we can solve together.

Why Birds Hit Glass

Solutions in Sight

ABC's Glass Collisions program is leading the way in finding solutions to this problem that plagues birds both common and rare throughout the year, wherever they are. We encourage systemic change, advocating for collision-reducing legislation, offering training for architects and developers, and empowering concerned individuals to push for change in their communities. We also provide education and practical support for implementing bird-friendly changes wherever you live and make it easy to find products and solutions for reducing collisions at home.



Frequently Asked Questions About Birds and Glass

Glass collisions kill vast numbers of birds in the United States each year. Yet most Americans know little about this danger, and even fewer are aware of the solutions available to help prevent...

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Preventing Glass Collis

Find a variety of bird-safe wi occur, including retrofits.

Learn More



Products That Prevent Collisions

Looking for glass for a new building, or a solution to fix existing windows? Search our comprehensive material database to find the right product.

View Products Database



ABC Glass Testing and Research

Discover how American Bird Conservancy researches and tests bird-friendly glass and other solutions to prevent window collisions. ABC's rating system assigns a Threat Factor™ score that indicates which materials birds are most likely to avoid during our tunnel testing process.

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Glass Collisions Related News & Stories

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Jersey City's Bird-Friendly Ordinance Will Make Skies Safer Along a Busy Migratory Route

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Sep 8, 2025

Bird-friendly Buildings



Your Backyard Can Be a Buffet for Birds... but You Need To Be a Good Caterer!

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Aug 31, 2025

Backyard Birds

Meet the Glass Collisions Team

ABC's Collisions Team carries out research to better understand the threat of window collisions, rigorously tests and evaluates products and solutions to prevent collisions, and supports change in communities through advocacy, education, and outreach.

Bryan Lenz
Glass Collisions Program Director Bird City Network Director

Read Bio



Kaitlyn Parkins
Glass Collisions Program Coordinator

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Christine Sheppard
Glass Collisions Program Director

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Anikó Tótha
Bird Collision Glass Testing Program Coordinator

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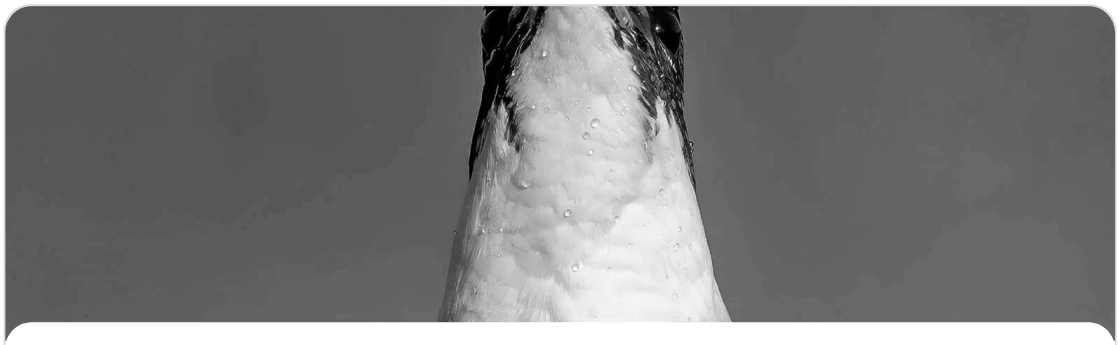
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ABC and partners work to restore the soaring forests with mature, tall trees, understories of young trees and shrubs, and open forest floor that represent ideal habitat for breeding Wood Thrushes. Photo by Som Prasad.

Explore ABC's Other Solutions



Addressing Fisheries

Fisheries can be a major threat to seabirds, whether by overfishing or bycatch. Explore American Bird Conservancy's solutions to make fisheries safer for birds like albatrosses, shearwaters, and petrels.

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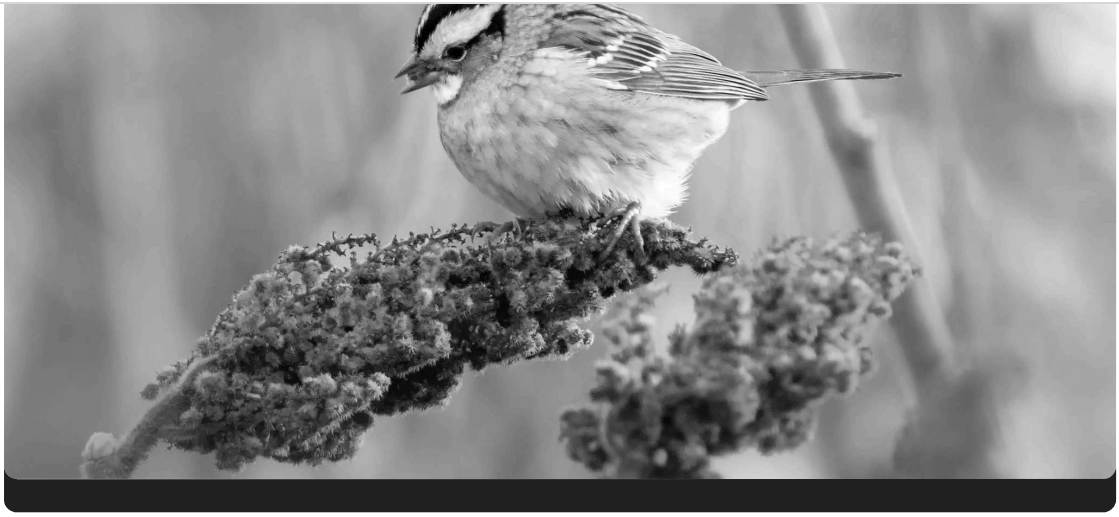


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Birds are facing a suite of th
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Related Birds



White-throated Sparrow

ZONOTRICHIA ALBICOLLIS

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Wood Thrush

HYLOCICHLA MUSTELINA

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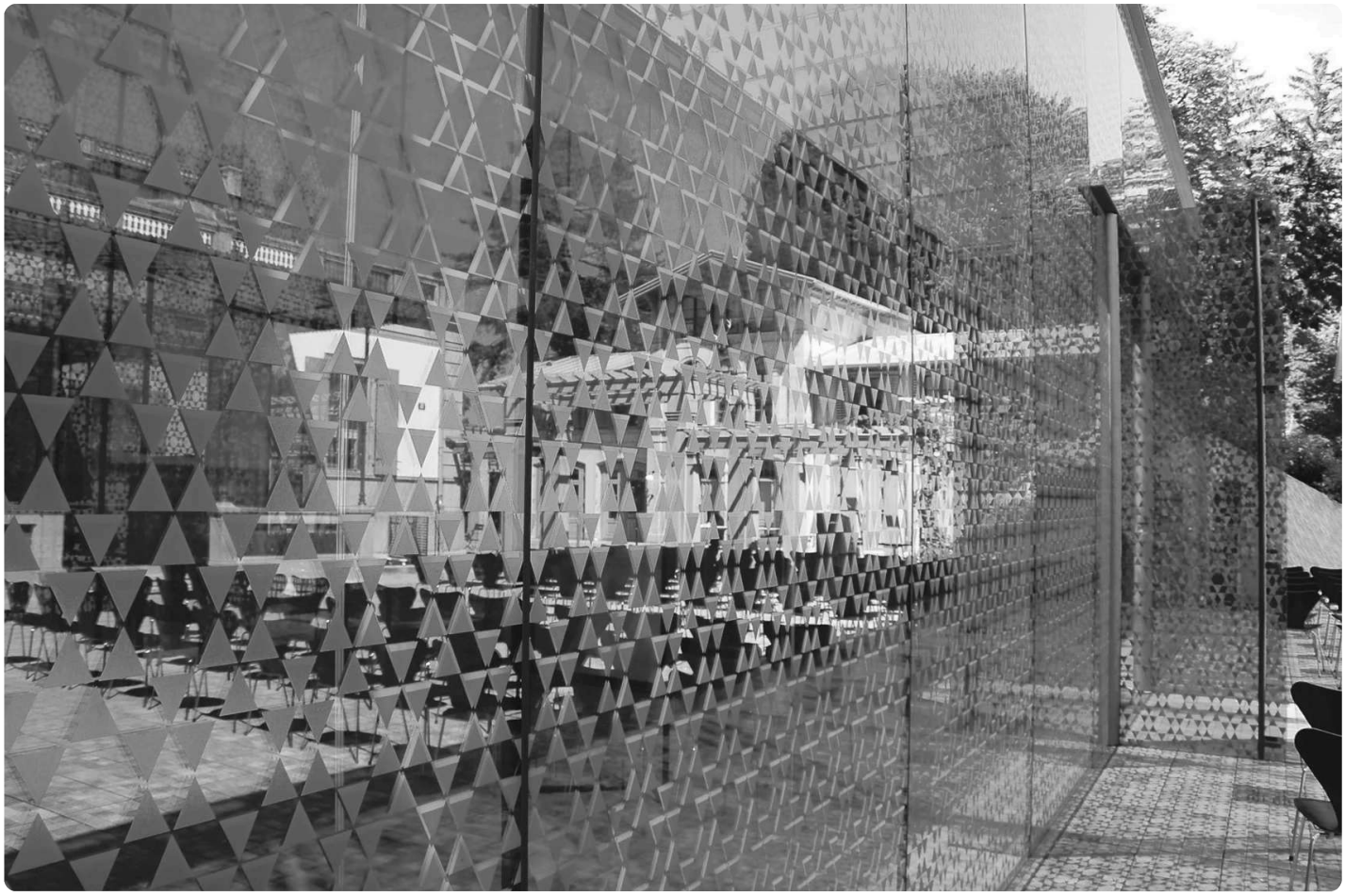
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Products



Museum Rietberg in Zürich. Photo by Hans Schmidt.

About this Products Database

No product can be guaranteed to stop all collisions in real world conditions. Glass can vary in appearance from one façade of a building to another or with time of day, depending on solar angle, reflected environment and other factors.

The Threat Factor^{tm} number is determined under standard conditions and does not capture that variety. Instead, Threat Factor is a relative index, and products with lower TFs are considered more effective at preventing collisions. A TF of 30 suggests that collisions will be reduced by at least 50 percent and is ABC's upper threshold for recommending a product.

Products with UV patterns should be considered carefully for some applications: Materials with ultra-violet patterns will vary in effectiveness with the amount of UV light present. This means that when the UV index is low – under low light conditions in early morning or evening or if the glass is shaded, or when it is overcast Skip to main content less visible to birds. In addition, not all types

of birds can see UV. For example, songbirds can see UV, raptors and pigeons cannot. Because Threat Factors can be effected by lower coatings, published Threat Factors apply only to the glass assembly tested.

Search Criteria

Are you a building professional or interested in home windows?

–Choose One–

1 - 10 of 240 results



Paint: Oil-based Pen

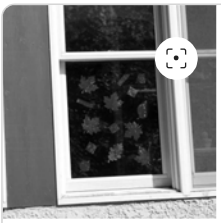
Any

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Image drawn on outside of window, using oil-based pen

Marker Type: Paint Pattern

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Window Alert Decals (multiple styles) 2×2″ spacing recommended

Window Alert

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Recommend installation with 2" x 2" spacing

Marker Type: Decal

Product Line: WindowAlert

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Glass: stained

Any Stained Glass

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Prescriptive rating

Marker Type: Low Reflection



Bird’s Eye View

Artscape Inc.

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Non-adhesive, easy to apply and remove; 2x2" spacing recommended. Although field tested on the inside surface by Dr. Daniel Klem, this was on uncoated window glass. ABC recommends them on the exterior surface only.

Marker Type: Decal

Product Line: Bird's Eye View

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Decals: bird silhouettes

Wandkings

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Place decals using 2"x2" spacing guidelines

Marker Type: Decal

Product Line: Bird and Window Protection Stickers

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Paint: Tempera

Any

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Use non-toxic paint to put up pattern or picture using 2x2" spacing guidelines

ABC Approved: Yes

Marker Type: Paint Pattern

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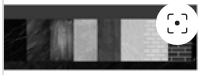
Paint: Acrylic

Any

Threat Factor: Variable. Effectiveness depends on visibility and spacing of visual markers.

Use non-toxic paint to put up pattern or picture using 2x2" spacing guidelines

Marker Type: Paint Pattern



Solar Siding

Mitrex

Threat Factor: 1

ABC Approved: Yes

Marker Type: No Reflection

Product Line: Solar Siding

Show More



Wood

Threat Factor: 1

Any wood without reflective paint

ABC Approved: Yes

Marker Type: No Reflection

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Vinyl

Threat Factor: 1

any vinyl that is not reflective

ABC Approved: Yes

Marker Type: No Reflection

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1 2 3 ... 24 Next »

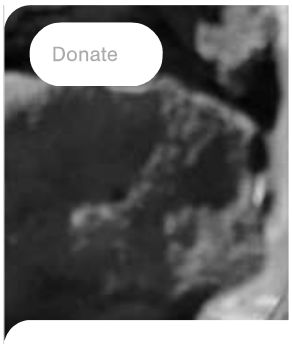
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Existing Bird-Fri

Many municipalities have en
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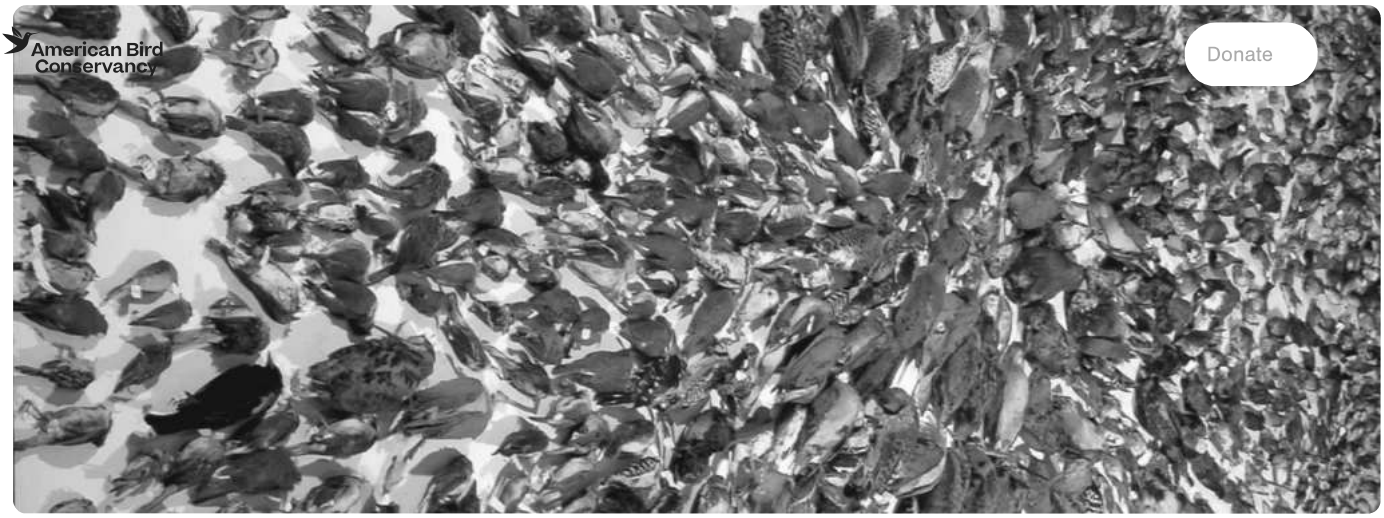
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Frequently Asked Questions About Birds and Glass

Glass collisions kill vast numbers of birds in the United States each year. Yet most Americans know little about this danger, and even fewer are aware of the solutions available to help prevent these deaths — fixes that in many cases are easy and inexpensive.



To shed light on this pervasive threat, ABC's collisions experts, Christine Sheppard, Ph.D., and Bryan Lenz, Ph.D., put together a list of responses to the 15 questions they are most frequently asked. Take a look. Chances are, we've got an answer for you below.



Birds killed by glass collisions in Toronto. Photo by FLAP/Kenneth Hrdy

1) How many birds are killed by glass collisions in the U.S. each year?

Because glass is used so widely, giving a definitive answer is difficult, but Smithsonian researchers attempted to do so in 2014.

They estimated that homes and other buildings one to three stories tall accounted for 44 percent of all bird fatalities, about 253 million bird deaths annually. Larger, low-rise buildings four to 11 stories high caused 339 million deaths. And high-rise buildings, 11 floors and higher, kill 508,000 total birds annually. Individual skyscrapers can be quite deadly for birds, but they kill fewer birds overall due to their limited numbers.

By combining these numbers, the Smithsonian reported that collisions likely kill between 365 million and 1 billion birds annually in the United States, with a median estimate of 599 million1.

We believe that the true number is closer to a billion, or higher, for several reasons. For one, data used in the study is now more than ten years old, and there has been a steady increase in glass use since that time, increasing the likelihood of fatal collisions. In addition, we've learned that bird carcass reports tend to underestimate deaths (see questions 4 and 5), meaning that more dead birds go uncounted than we realized.

This means that the only anthropogenic (human-caused) threat that kills more birds in the United States each year is domestic cats2.

2) Why do birds collide with glass?

Transparent glass is invisible to both humans and birds, but humans can use door frames and other visual clues to anticipate the presence of glass and avoid collisions — most of the time. Birds, of course, don't share this ability. They perceive reflected images as literal objects, which explains why glass reflections, especially ones that present images of food, shelter, or an escape route, can trigger collisions. Learn more by visiting our "Why Birds Hit Glass" page.



Reflections can draw birds toward windows. Photo by Christine Sheppard

3) Are birds okay when they hit windows and fly away?

After colliding with glass, some birds may be only temporarily stunned and without lasting injury — but often they are not so lucky.

In many of these cases, birds suffer internal hemorrhages, concussions, or damage to their bills, wings, eyes, or skulls3. While they may be able to fly temporarily, birds with even moderate injuries are much more vulnerable to predators and other environmental dangers.

In many instances, however, birds are killed immediately and never fly away.

4) Why don't I see birds that have been killed by collisions more often?

Collisions often go unnoticed at both homes and commercial buildings for several reasons. First, many of the birds that hit windows do not die immediately and fly off without leaving a trace.

One study found that, out of 29 window collisions, only two birds died immediately and left a carcass that at the foot of the window4. However, birds can sustain severe injuries such as fractured bones and beaks, concussions, and internal bleeding3, so even birds that initially fly away likely die elsewhere.

Second, for those birds that do die and end up at the base of the building, animal scavengers often quickly remove carcasses. Cats, raccoons, birds of prey, and even squirrels, can learn to wait at windows where collisions occur for an easy meal.

Birds may also fall on inaccessible rooftops, fall through grates, end up in landscaping, or land in dense vegetation that makes them difficult to see.

5) Do collision monitoring programs find all collision victims?

Even for intensive collision monitoring programs the total number o ‹ always a large underestimate of the number of birds that actually collided with the glass. This is the cas ɔ the answer above.

Skip to main content

Many of the birds that hit windows do not die immediately and fly off without leaving a trace. One study found that, out of 29 window collisions, only two birds died immediately and left a carcass that at the foot of the window4. However, birds ca vere injuries3, so even birds that initially fly away might die elsewhere.

Second, for those birds that do die and end up on the ground, animal scavengers – and people, frequently facilities teams – often remove carcasses before monitors can find them. Collision monitors even report animals, such as gulls and squirrels, learning to wait at windows where collisions occur for an easy meal. This problem is so serious that academic monitoring efforts conduct “carcass persistence studies” to estimate the number of dead birds removed before monitors walk their routes and find them5,6.

The rate at which dead and injured birds disappear can vary a lot from site to site7; researchers have found that in some places carcasses are removed within hours8 while at others it takes days5,6,7. At some locations in NYC, for example, only 25% of carcasses placed on collision monitoring routes remained when collisions monitors walked their routes later the same morning8.

Finally, for those birds that are left, monitors do not always detect all of them9. Birds may fall on inaccessible rooftops, fall through grates, end up in landscaping, land in dense vegetation that makes them difficult to see, be swept away in the gutter, or just overlooked because they blend in with the ground.

In one study where researchers accounted for both scavenging and imperfect detection, they estimated that only about 20% of birds killed were actually found by people who were searching for them9. So, it is safe to say that any number of birds picked up in a monitoring effort especially if it is not a rigorous monitoring effort, is going to be a small fraction of the birds that actually died and an even smaller fraction of the total number of birds that hit the windows.

6) How do I stop birds from hitting my windows?

There are many ways to making windows bird-friendly. One of the best is to use external insect screens. These screens virtually eliminate reflections, and if birds do hit them, the impact is cushioned, reducing the likelihood of injury. An added benefit is that these screens are easy to install on existing or new home windows.

If screens aren’t an option, you can use a range of materials — tape, decals, strings, cords, paint, netting, and shutters are options — to create window patterns that birds will interpret as solid objects, needing to be avoided. Check out our great home-friendly solutions guide here.

It’s important to make sure that birds see no viable way to fly between the markers or objects you’re using, so make sure to eliminate all spaces larger than two inches.

Remember, whichever material you use needs to be visible to birds from at least ten feet away so that they have time to see the material and change course.



Bird-friendly window products are effective, inexpensive, and easy to install. Photo by ABC

7) Can I apply something to the inside of my windows to stop bird collisions?

The best place to apply solutions is on the outside of the window, where they are easily visible.

However, using external solutions isn't always an option. Some windows — like those on tall buildings — can be difficult to access from the outside.

In these cases, we recommend testing a variety of solutions. This is because different kinds of glass have varying reflective levels and, unfortunately, there is no universal solution.

To conduct a test, apply a sticky note, tape, or sample of your proposed solution to the inside of the window and then look at it from the outside every hour or two, starting in the early morning.

If you can see your test material most of the time, birds will too, and an inside solution may work for you.

In many cases, however, internal solutions do not work, and reflections will hide your solution during part or all of the day, thereby reducing or eliminating its effectiveness.

But this shouldn't deter you from acting. is better than doing nothing. Adding something to your windows is better than doing nothing.



The intensity of window reflections varies during the course of the day, affecting the danger to birds. Photo by Christine Sheppard

8) Will bird-friendly window products obscure the view from my window?

No, you don't need to impair your view to save birds.

There are effective solutions that cover as little as 1% of the window area, allowing sunlight in and a view out. In our experience, people quickly adjust to bird-friendly design solutions, often forgetting that they are even there. We have also found that when family, friends, or customers notice the pattern and learn its purpose, they appreciate the effort to protect birds.

If you're looking to retrofit existing windows, there is a wide range of solutions from which to select, depending upon personal preferences.

If you are designing a new building or replacing windows, consider the professional solutions favored by architects. Many of these elegant products have enjoyed long-standing popularity among architects for their aesthetic appeal alone. For more on designing a new building or replacing windows, visit the "Resources for Archite

Skip to main content

elopers" page. Looking for inspiration? Check out our bird-friendly building gallery.



Bird-friendly window products have little impact on views. Photo by Arenal Observatory Lodge

9) Does light cause birds to hit buildings?

Light can increase collision numbers in several ways. Recent studies confirm that urban glow attracts birds into the human-built environment[10,11], where they run a higher risk of collisions.

Migratory birds traveling at night are also attracted by intense lights contrasted against the night sky. The “beacon effect,” as this occurrence is commonly known, can be caused by lighthouses, offshore oil platforms, or powerful light displays, like the twin beams at the 9/11 Tribute in Lights memorial in New York City. These lights can thoroughly disrupt birds’ ability to navigate, pulling them off course and effectively trapping them around the light12 or disorienting them. At the 9/11 memorial, volunteers monitor the birds and the lights are turned off when needed to allow safe passage.

Brightly lit building facades can also affect birds. In some cases, these facades and brightly lit windows can cause collisions at night[13,14]. These birds are seen fluttering at lit windows or exhausted on the ground14 where they are vulnerable to predators.

Despite the dangers posed by nighttime lights, it’s important to note that most collisions take place during the day. These collisions are due to habitat reflected in or seen through glass, and they are often direct and deadly.

While turning off lights is a great way to help birds and other wildlife, the best way to prevent collisions, especially at homes, is to use one of the many options available to treat your windows.





Skip to main content

The World Trade Center memorial light has a “beacon effect” upon birds. Photo by jnap/Flick. Houston, [illegible] monstrates the growing impact of light pollution. Photo by NASA

10) I put a decal up, but birds still hit my windows. What can I do?

A single decal may be enough to warn an alert human to expect a glass door, but for a bird it's simply an obstacle to fly around.

To successfully deter birds, decals and other collision deterrents must be applied with proper spacing to create the illusion of a cluttered environment through which it would be difficult or impossible to fly. You can learn more here. Remember to make sure that whichever pattern you use on your windows should not have any spaces more than two inches wide.

11) What can I do about a building that causes collisions in my town?

The first thing to do is document the problem. Take photos of the dead birds you find and keep a list of numbers and dates.

If there is a facilities or maintenance department, ask what they have noticed; they are usually responsible for cleaning up birds that have died after hitting glass and may be great allies who help you collect data or convince building managers of the danger to birds.

After documenting the problem, review the window solutions on ABC's site, contact the building owner or manager to tell her or him about the problem, and provide advice or resources (such as this blog) on how to address it.

Keep in mind that you are making a request and looking for a partner to save birds, so be sure to keep these interactions positive and non-confrontational. Avoid vilifying the responsible party for a collision problem that they likely had no idea existed.

You can also talk to people who live, work, or shop in the building in question to see if anyone else shares your concerns. If so, ask them if they would like to be involved. By working with others, you build a collective voice that can draw more attention to the problem.

Remember, there are many ways to get involved. These include helping with monitoring, writing letters to building owners, attending meetings with building management, and organizing community action.

For more tips see our "How to Advocate for Retrofits" page.



Window imprint from bird collision. Photos by David Fancher

12) What can I do to keep buildings that harm birds from being constructed where I live?

Buildings designed without bird-friendly design principles have the potential to be deadly for birds.

A variety of factors determine the level of the threat they pose, including the amount of glass used, placement and reflectivity of the glass, the height and extent of vegetation around the building, and the presence of water, among other things.

Given incremental cost of constructing a bird-friendly building, we believe that all new buildings — not just glass-covered skyscrapers — should incorporate bird-friendly features. It is less expensive to incorporate these features from the beginning of the planning process, compared to retrofitting a building later.

There are several ways to help make this happen. The first is to develop and pass a local ordinance requiring the adoption of bird-friendly building standards in your community. To download an easy-to-use ordinance template, click here. You can also take a look at our list of existing ordinances mandating bird-friendly design or creating voluntary standards.

Keep in mind that ordinances tend to apply to large buildings and exempt low rises and homes, so it is important to make sure that the ordinance applies to as many buildings as possible.

Although passing an ordinance is a great accomplishment, it's not the only thing you can do.

Consider approaching the developers of new and proposed building projects with your concerns. Since this can be a time-consuming process, we suggest focusing on projects with a high likelihood of success (e.g., nature centers, museums) or organizations that influence multiple buildings (e.g., local government, universities, health care organizations, and architecture firms) to help them adopt bird-safe building policies.

While it's critical to make sure that new buildings incorporate bird-friendly designs, don't forget that existing buildings already account for hundreds of millions of bird deaths annually. Consequently, the need to retrofit homes and other buildings will remain an important way to reduce bird collisions for the foreseeable future.

To learn more visit our "Creating Bird-Friendly Legislation" page.



Bird-friendly building design can improve a building's appearance while reducing bird deaths. Photo by Almere

1. Loss, Scott R., Tom Will, Sara S. Loss and Peter P. Marra. 2014. Bird–building collisions in the United States: Estimates of annual mortality and species vulnerability. Condor 116:8-23. https://doi.org/10.1650/CONDOR-13-090.1
2. Loss S.R., Will T., and Marra P.P. 2013. The impact of free-ranging domestic cats on wildlife of the United States. Nature communications 4(1):1-8. https://doi.org/10.1038/ncomms2380
3. Klem, D., Jr. 1990. Bird injuries, cause of death, and recup with windows. Journal of Field Ornithology 61(1):115- 119. https://www.jstor.org/stable/4513511

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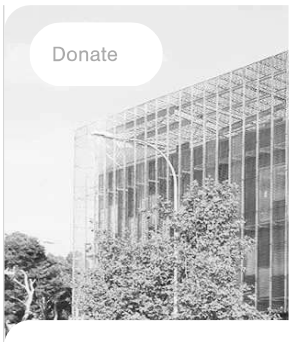
4. Samuels B, Fenton B, Fernández-Juricic E, & MacDougall-Shackleton SA. 2022. Opening the black box of bird window collisions: passive video recordings in a residential backyard. PeerJ 10:e14604 https://doi.org/10.771 04
5. Kummer, J. A., C. J. Nordell, T. M. Berry, C. V. Collins, C. R. L. Tse, and E. Bayne. 2016. Use of bird carcass removals by urban scavengers to adjust bird-window collision estimates. Avian Conservation and Ecology 11(2):12. http://dx.doi.org/10.5751/ACE-00927-110212
6. Riding, Corey S. and Scott R. Loss. 2018. Factors influencing experimental estimation of scavenger removal and observer detection in bird–window collision surveys. Ecological Applications 28(8): 2119-2129. https://doi.org/10.1002/eap.1800
7. Hager, Stephen B., Bradley J. Cosentino and Kelly J. McKay. 2012. Scavenging effects persistence of avian carcasses resulting from window collisions in an urban landscape. J. Field Ornithol. 83(2) 203-211. https://doi.org/10.1111/j.1557-9263.2012.00370.x
8. Parkins, Kaitlyn L, Susan B. Elbin and Elle Barnes, 2015. Light, glass, and bird–building collisions in an urban park. Northeastern Naturalist 22(1): 84- 94. http://dx.doi.org/10.1656/045.022.0113
9. Bracey, Matthew A. Etterson, Gerald J. Niemi, and Richard F. Green. 2016. Variation in bird-window collision mortality and scavenging rates within an urban landscape. The Wilson Journal of Ornithology 128(2):355-367. https://doi.org/10.1676/wils-128-02-355-367.1
10. La Sorte FA, Fink D, Buler JJ, Farnsworth A, and Cabrera-Cruz SA. 2017. Seasonal associations with urban light pollution for nocturnally migrating bird populations. Glob Change Biol. 23:4609–4619. https://doi.org/10.1111/gcb.13792
11. McLaren, J. D., Buler, J. J., Schreckengost, T., Smolinsky, J. A., Boone, M., Emiel van Loon, E., Dawson, D. K. and Walters, E. L. 2018. Artificial light at night confounds broad-scale habitat use by migrating birds. Ecol Lett. 21(3):356-364. https://doi.org/10.1111/ele.12902
12. Van Doren, Benjamin M., Kyle G. Horton, Adriaan M. Dokter, Holger Klinck, Susan B. Elbin and Andrew Farnsworth. 2017. High-intensity urban light installation dramatically alters nocturnal bird migration. Proc Nat Acad Sci: 114 (42) 11175–11180. https://doi.org/10.1073/pnas.170857411
13. Van Doren, Benjamin M., David E. Willard, Mary Hennen, Kyle G. Horton, Erica F. Stuber, Daniel Sheldon, Ashwin H. Sivakumar, Julia Wang, Andrew Farnsworth, and Benjamin M. Winger. 2021. Drivers of fatal bird collisions in an urban center. PNAS 118(24):e2101666118. https://doi.org/10.1073/pnas.2101666118
14. Korner, P., von Maravic, I. and Haupt, H. Birds and the 'Post Tower' in Bonn: a case study of light pollution. J Ornithol 163, 827–841 (2022). https://doi.org/10.1007/s10336-022-01985-2
15. Gelb, Y. and N. Delacretaz. 2006. Avian window strike mortality at an urban office building. Kingbird 56(3):190-198. https://nybirds.org/KBsearch/y2006v56n3/y2006v56n3p190-198gelb.pdf
16. Hager SB, Craig ME. 2014. Bird-window collisions in the summer breeding season. PeerJ2:e460. https://dx.doi.org/10.7717/peerj.460
17. Kahle LQ, Flannery ME, and Dumbacher JP. 2016. Bird-window collisions at a west-coast urban park museum: Analyses of bird biology and window attributes from Golden Gate Park, San Francisco. PLoS ONE 11(1): e0144600. https://doi.org/10.1371/journal.pone.0144600
18. Riding, C.S., O'Connell, T.J. & Loss, S.R., 2021. Multi-scale temporal variation in bird-window collisions in the central United States. Scientific Reports 11(1):1-12. https://doi.org/10.1038/s41598-021-89875-0
19. Borden, W.C., O.M. Lockhart, A.W. Jones and M.S. Lyonn. 2010. Seasonal, taxonomic and local habitat components of bird-window collisions on an urban campus in Cleveland, OH. Ohio J Sci 110(3):44-52. https://kb.osu.edu/handle/1811/52787
20. Scott KM, Danko A, Plant P, Dakin R. 2023. What causes bird-building collision risk? Seasonal dynamics and weather drivers. Ecology and Evolution 13(4):e9974. https://doi.org/10.1002/ece3.9974
21. Brown B.B., L. Hunter, and S. Santos. 2020. Bird-window collisions: different fall and winter risk and protective factors. PeerJ 8:e9401 https://doi.org/10.7717/peerj.9401
22. De Groot, Krista L., Porter Alison N., Norris Andrea R., Huang Andrew C., Joy Ruth. 2021.Year-round monitoring at a Pacific coastal campus reveals similar winter and spring collision mortality and high vulnerability of the Varied Thrush, Ornithological Applications 123(3):duab027. https://doi.org/10.1371/journal.pone.0144600
23. Dunn, E. H. 1993. Bird mortality from striking residential windows in winter. Journal of Field Ornithology 64(3):302-309. https://www.jstor.org/stable/4513821



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Up to 95% reduction in bird-glass collisions.

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Meets bird-safe standards and guidelines.

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Saving birds in over 48 countries



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"We put this on a large picture window 2 years ago and have not had a single bird fly into it! At first you kind of look at the little fits and think what did we do….but don't notice them at all anymore. Before installing I would say 10 birds a year hit the window ranging from a chickadee to a hawk! Highly recommended if you care about wildlife."

★ ★ ★ ★ ★

Michael C.

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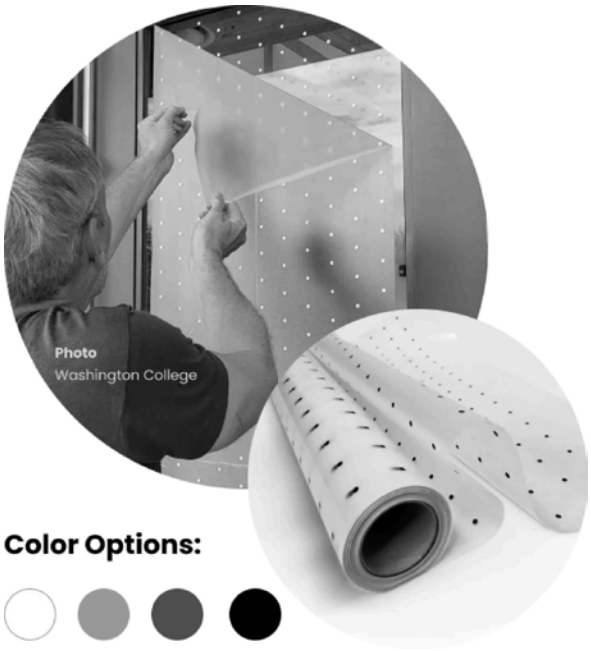
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Can be installed in temperatures as low as -20°C, allowing for year-round installation, even in colder climates

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Color Options:

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Bird collisions reduced by over 95%, demonstrated by independent studies and real-world results.

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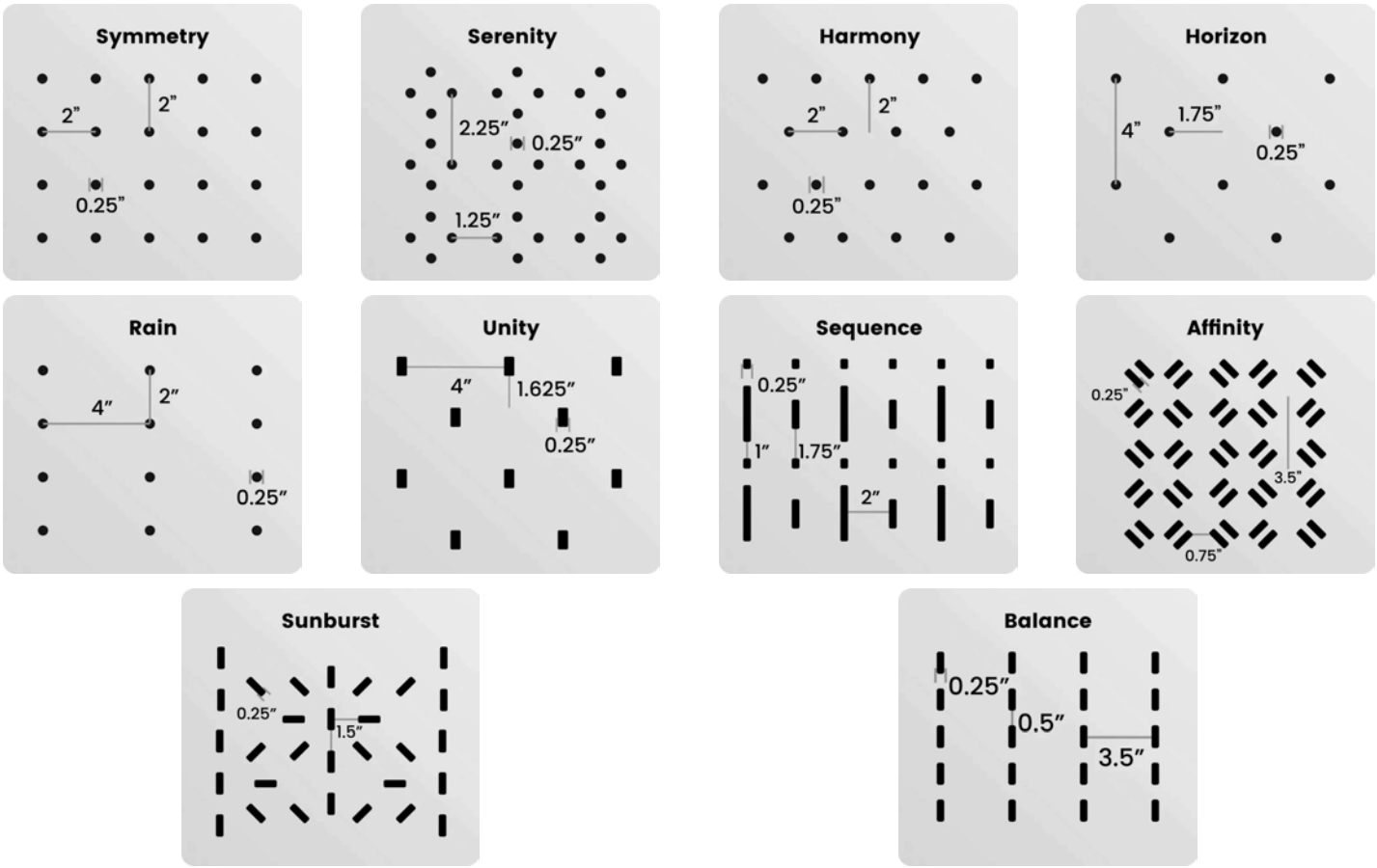
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"Forget about the fact that they save birds. They just look cool."

Why do birds sometimes fly into glass?



"Hummingbirds were always flying into a big picture window at our mountain house. Since installing the BirdSavers we haven't had any fly into the window."

-- Diane B., Mineral Bluff, GA
(BirdSavers in place for 7 months.)

See all 140 user comments about BirdSavers here



"The BirdSavers are on every window of our passive solar house, all 17 of them. BirdSavers are truly just that -- they save birds! We had multiple fatal strikes every year until we installed these marvellous cords. Swallows, starlings, kingbirds, sparrows, finches, even a pheasant. We were heartbroken with every one and tried everything we could find: decals, CDs hung on fishing line, mylar streamers. Nothing worked. But BirdSavers do! We have had them for over 4 years now and have had no bird strikes! We couldn't be more pleased with the way they work, the way they look, the easy installation and everything about them. BirdSavers are miraculous -- they do what they promise and do it simply and easily. We encourage everyone to "stop the thuds" and install Acopian Birdsavers. The birds will thank you! I believe in every word I wrote and we will always be grateful to Acopian BirdSavers. Thanks, Jeff!"

-- Lynn Walker, Ritzville, WA

"After three years of increasing problems with orioles, cardinals and robins hitting our windows, I came across the Acopian website. I followed the directions and made Zen Wind Curtains for seven of our windows.... easy to make and attach. What a difference they have made. Since they have been up, we have had no deaths of birds flying into the windows. The BirdSavers do not interrupt our views. Cleaning windows is easy, and does not require removal. We have had the curtains in place now for several years, and have shared the BirdSavers web site with other interested friends. They are a great solution... and such an easy solution, if only people knew about them. I am also impressed that while the site also sells the curtains pre-made, the instructions to "make your own" are shared for free, and are so easy to follow, so as to make them readily available. Acopian BirdSavers is a successful, inexpensive and attractive answer to help save our winged friends!"

-- BirdSavers DIYer, Iowa

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"The BirdSavers are on the outside of large sunroom windows. A bird feeder is about 25 feet away. Before I put the BirdSavers up I was going to take the feeder down as too many birds hit the sunroom windows. The BirdSavers were installed three years ago or so and not one bird has hit my windows since then. None. They are amazing. I am totally satisfied with the results. They resulted in NO Bird strikes for over three years. They also look good on the Windows. We barely see them when we look out the windows in our sun room. I highly recommend this product to everyone who wants to prevent bird deaths from strikes."

-- Peggy Brennan, North Haven, CT
(BirdSavers in place for 2 years, 11 months.)

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Some quick and simple measurements are all that are needed for you to order custom hand-made, cool looking Acopian BirdSavers for your windows! Or use our simple instructions to make DIY BirdSavers yourself.

"Acopian BirdSavers offer a practical and effective way to reduce window kills. I recommend them wholeheartedly."

-- Keith L. Bildstein, Ph.D.
Professional Ornithologist and Conservationist

A Simple Way to Save Birds!

When people think of bird mortality they usually think of cats, wind turbines, and pesticide poisoning, among other causes. In fact, in North America the largest number of birds are killed each year by glass!

Listen to BirdSavers on the radio:

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- Laura Erickson's For The Birds show

Scientific paper downloads about Acopian BirdSavers (PDF):

- "Evaluating the Effectiveness of Acopian BirdSavers to Deter or Prevent Bird-Glass Collisions" by Dr. Daniel Klem, Jr.

Acopian BirdSavers can be used to comply with the "LEED Credit Pilot 55 - Bird Collision Deterrence". Prevent birds from flying into windows.

Please print and display (or handout) any of these BirdSavers materials if you want people to know about this easy, elegant, inexpensive technique to prevent birds from dying at our windows.

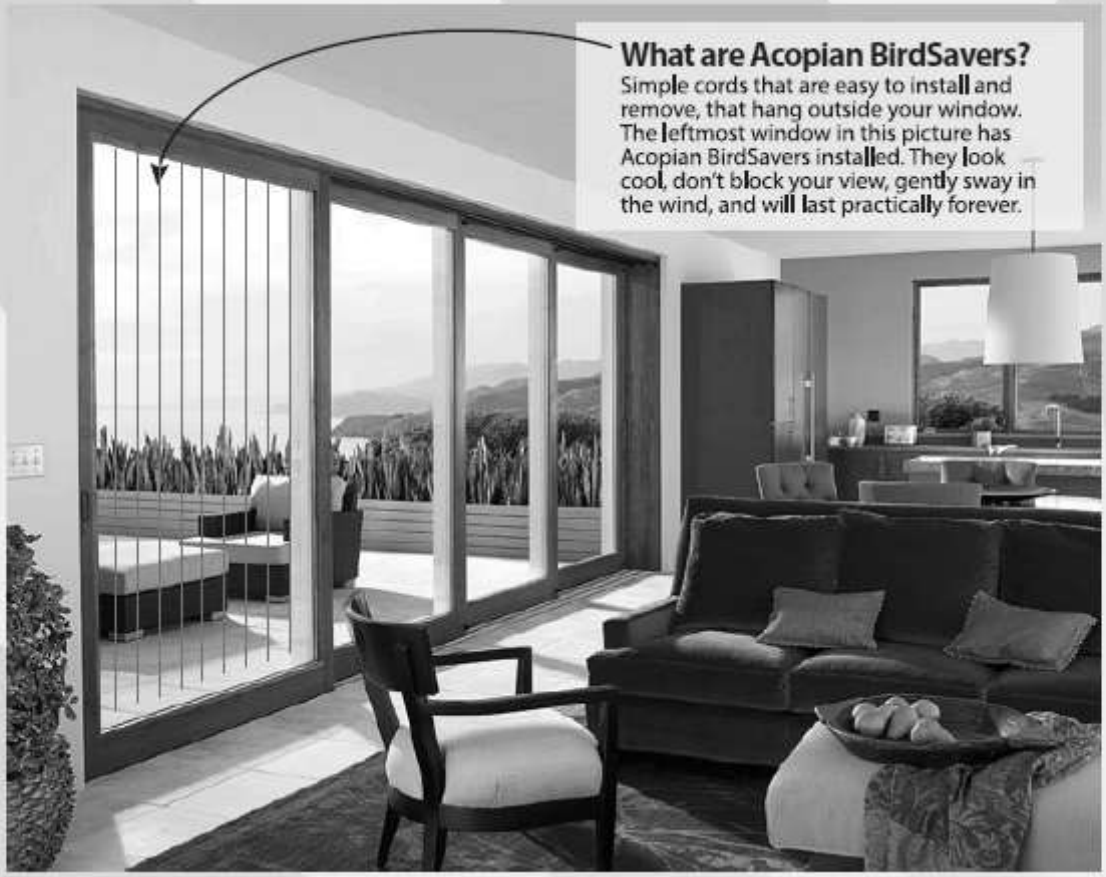
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Very elegant solution - Very simple design - It works!

AcopianBirdSavers

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major problem s this design, they will be convinced that it should be at the top of anyone's arsenal of techniques who desires to easily prevent bird¬-window collisions. A vast majority of people who have Acopian BirdSavers on their windows or have seen Acopian BirdSavers on windows, if they even notice them, admire the aesthetic look of them. And people who have them on their windows are happy to not be killing birds anymore.

I feel great satisfaction when BirdSavers are used because house or building aesthetics are not compromised, birds are being saved, and people are happy with the results.

- Jeff Acopian
Easton, Pennsylvania

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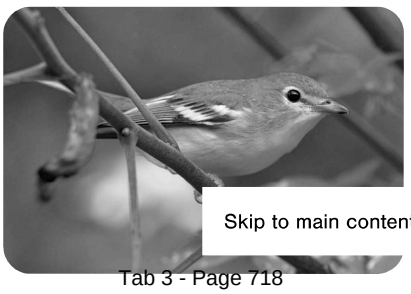
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ABC Glass Testing and Research

Discover how American Bird Conservancy researches and tests bird-friendly glass and other solutions to prevent window collisions.





Testing Bird-Friendly Products

Glass windows kill more than a billion birds in the United States each year, making them one of the deadliest threats to birds. Birds don't recognize glass as something solid — they perceive reflections of habitat, sky, and vegetation in glass, or see through glass to habitat on the other side. To make windows safer for birds, we need to make glass that birds can see. It's impossible to ask a bird what it can see, but ABC's glass testing program is about as close as we can get to an answer.

Two Glass Testing Tunnels

We test birds' reactions to patterned glass using two glass testing tunnels — the only ones in the U.S. ABC started testing glass in 2010 at Carnegie Museum of Natural History's Powdermill Avian Research Center (PARC), a permanent bird-banding station in Rector, Pennsylvania that bands more than 11,000 birds of more than 110 species in a typical year. In 2022, we expanded our glass testing capacity, joining forces with Washington College to establish a second glass testing tunnel at the college's Foreman's Branch Bird Observatory in Chestertown, Maryland.

On the outside, the testing tunnels — 24-foot-long, narrow constructions of plywood — look unusual, but the tunnels are scientific tools. By watching how birds fly through them, we can identify which glass materials birds can see, and which ones they can't.



Bird_Safe_Windows

American Bird Conservancy

05:20



About the Rating System

ABC's rating system assigns a Threat Factor™ score that indicates which materials birds are most likely to avoid during our tunnel testing process.

Learn More (DOC)

White-browed Tit-Spinetail.

Photo by Greg Lavaty, www.texastargetbirds.org.

Setting Up the Testing Tunnel

Birds are safely caught in mist nets (fine mesh netting used to gently capture birds) and retrieved by trained professionals. All personnel handling birds for the glass testing tunnels are experienced bird handlers under the supervision of a Master Bander operating under a federal permit from the U.S. Geological Survey's Bird Banding Lab.

Birds mist-netted on trails near the banding station are removed from the nets by banding technicians, placed in cloth bags, and taken to the station for banding and measuring. After banding, birds chosen to be tested in the tunnel are put back into a cloth bag and brought to the tunnel.

When a bird is brought to the tunnel for testing, the tunnel-testing technician removes it from the bag and evaluates it. Any bird that appears stressed is safely released without being put through a tunnel trial. For birds in good condition, the band number is recorded and the bird is released into the tunnel by hand through a sleeve set into the tunnel's end panel. Any bird that does not fly after 30 seconds in the tunnel is withdrawn and released.

Flight Testing

Birds are placed in a 24-foot-long tunnel, constructed of plywood and particle board over a steel frame. The tunnel is open and lighted at one end with two panes of glass mounted 18 inches from the opening. This presents birds with a choice for how they will exit: via an "invisible" panel of plain glass that serves as a control or a panel of the patterned material being tested. A taut mist net stops the birds before they reach the glass, and each bird is released back into the wild after a single test flight.

Birds are observed and recorded as they fly through the tunnel. A bird's flight type, as well as where it goes — towards the "invisible" control glass, the treated glass, the walls of the tunnel — gives us insight into how each bird perceives its surroundings.



Bird's eye view of the way out! Photo by Chris Sheppard



The banding crew examines a bird and records measurements. Photo by Chris Sheppard

Tunnel Operations

Consistency matters, and the tunnels have some special features to ensure the efficacy of the trials. Each tunnel is mounted on a pivot and is rotated every five minutes to keep a constant orientation, with the sun always directly behind the operator. Mirrors at the sides of the tunnel reflect ambient light onto the front surfaces, the "bird approach side" of the glass. Greatly reduced natural light falls on the back surface of the glass, mimicking the lighting differential between indoors and outdoors in buildings.

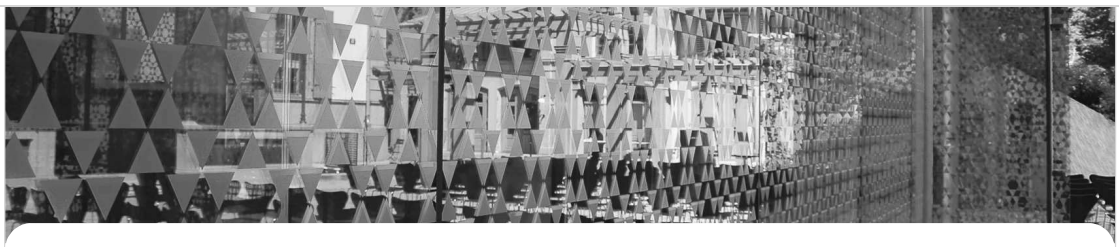
Test materials (the treated glass) are presented in random order and in equal frequency on the left and right sides. At regular intervals, proofing trials using two clear panes or no glass are run as a control. During these trials, equal numbers of flights to left and right indicate that the tunnel itself is not influencing the choice made by the birds.

Determining the Material Threat Factor(tm)

ABC's rating system assigns a Threat Factor^{TM} score that indicates which materials birds are most likely to avoid during our tunnel testing process. We score at least 80 trials per tested material to account for environmental variation and the fact that we are running trials with a variety of bird species. The observations of birds in flight are analyzed, and from that data, we can assign a Material Threat Factor (TF) based on how many birds fly toward the glass. If birds avoid it, that means they can see it. ABC defines the Material Threat Factor for a pattern or material as the percentage of birds tested that flew toward that material. So, if 20 of 80 birds fly toward the tested glass, 20/80=25% and the TF=25.

The Material Threat Factor is a key component of our Products and Solutions Database. It's a reflection of how well birds recognized the glass during trials. The lower the TF, the more effective the glass will be in reducing collisions. ABC defines "bird-friendly" materials as having a threat factor ≤ 30, corresponding to a conservative estimated reduction of collisions of at least 50% under real-world conditions.

To request glass testing and a Threat Factor^{TM} or to learn more, please contact Christine Sheppard, Senior Director, ABC Glass Collisions Program.



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Looking for glass for a new building, or a solution to fix existing windows? Search our comprehensive material database to find the right product.

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BUILDING CHRONICLE

Kendeda Building's bird-safe glass: Small step in 'shockingly huge' issue

By Ken Edelstein on April 26, 2019



Smack! We looked outside and saw him on the porch. A male house finch, or maybe a purple finch. Lying on his side. Eye wide open.

I slid open the glass door with which he'd just collided. He didn't give me a chance to play emergency medic, though.

The little songbird shook off the daze, righted himself and zipped straight out into the world — as directly as possible away from his bad experience with a strange invisible object. Even then, he wasn't out the woods.

Our afternoon visitor may have sustained enough of a head injury to become part of a stunning body count. According to the most extensive analysis of the topic, 365 million to 988 million birds die in the United States annually after flying into windows. Aside from habitat loss and cats, building collisions are the top human-related killers of avian creatures.

Contrary to popular imagination, skyscrapers cause only a fraction of those deaths. Millions of buildings below 10 stories have turned the urban and suburban landscape into a vast maze — right

at most birds' flight levels and spotted with reflective booby traps.

"Birds didn't evolve to handle windows," says the American Bird Conservancy's Christine Sheppard, perhaps the nation's leading advocate on bird collision deaths. "There is no transparent barrier in nature. This is something that humans have invented."

The Kendeda Building for Innovative Sustainable Design would fall right in the sweet spot (if that's the right term for it) of those booby traps, if it weren't for a commitment to bird-safe glass that bird advocates hope will be much more common in buildings. It features 9,500 square feet of window glazing from ground level to about 30 feet above grade. Surrounded by trees and an edible landscape of berries and flowers, all that glass threatens to reflect an inviting landscape for tanagers, buntings, hummingbirds and other species. But about a third of those windows include a simple dot-matrix pattern that could save hundreds of birds over the life of this one single building.

Surprisingly — especially considering the outsize role that birds play in nature — bird-friendly design hasn't gotten much attention from green-building certification programs. LEED offers an optional one-point Pilot Credit for bird-safe windows and other "collision deterrence" measures. The U.S. Green Building Council doesn't collect data on how many projects take advantage of that credit, but it's likely to be a small number.

The more rigorous Living Building Challenge doesn't mention bird-friendly design or bird-safe windows. Part of the problem is that LBC doesn't lend itself as easily as LEED to prescriptive solutions, because it's based on broad mandates rather than a checklist of options.

But ornithologists and advocacy groups, backed by the nation's multitudes of birders, are bringing attention to the issue. Adam Betuel came to Atlanta three-and-a-half years ago as conservation director of the local Audubon Society. Among his first projects: Mobilize volunteers to get a better idea of how many and what species of birds were being killed by area buildings.

The findings of his volunteer-driven survey have been sobering. Patrolling a tiny fraction of all the buildings in the region and with little access to private spaces, Project Safe Flight Atlanta has so far tallied more than 1,300 deaths spread among more than 100 species.

“By far, it’s one species more than any other: the ruby-throated hummingbird,” Betuel notes. “After that, comes the Tennessee warbler, which stops in Atlanta during its fall migration.”

Those two hardest-hit species are followed by the American robin and the cedar waxwing. Migratory songbirds dominate the top of the list, and research shows that’s probably the case across the country. There are two likely reasons: Temporary residents don’t have time to get to know the local landscape. And, while here, migratory birds are very actively foraging food to fuel their journeys.

Bird-safe buildings: a rare species

With the issue’s profile rising, Betuel’s Audubon chapter has received $75,000 in grants from the Disney Conservation Fund to treat six metro Atlanta buildings with bird-friendly window film. Retrofits usually aren’t as effective as pre-construction bird-friendly design or permanent bird-safe glass.

Betuel knows of only one building in the state — Zoo Atlanta’s new reptile house — designed and built with bird-safe glass. But, in 2016, the Kendeda Fund and Georgia Tech announced their commitment to construct a Living Building.

“I remember thinking that it would be sad for [the Kendeda Building] to be built and to have all these eco-friendly features but also to be contributing to bird deaths,” Betuel says. “Eco-friendly buildings can be worse for birds, because they typically have a lot of windows and they also tend to have trees and plants around them.”



A Disney Foundation grant underwrote Atlanta Audubon's drive to retrofit six metro Atlanta buildings with bird-safe film. Among them: the Chattahoochee Nature Center (above) . Photo by Adam Betuel.

It was Betuel who tracked down Kendeda Building design team leader Joshua Gassman to lobby for bird-friendly features. His spiel quickly got the Lord Aeck Sargent architect's attention.

"It's a shockingly huge issue," Gassman recalls thinking. "He was coming to us fairly late in the design process. But let's just say this fell on receptive ears. I could tell right away that this is something we should be concerned about."

Cost was a concern. That's often the case for green features that are proposed *after* a building's general design has been set. Unbeknownst to Gassman, however, Beutel and his colleagues were working another angle. Diana Blank, the philanthropist who founded the Kendeda Fund, happens to be an avid birder. When she learned of the problem from a friend who was a past Atlanta Audubon

board chair, Blank offered to add money for bird-friendly glass to the project's budget. (The added expense turned out to be $32,000 — less than a fifth of a percent of total construction cost.)

"I've been a bird watcher with a life list for years, and honestly I did not think over all that time, 'Oh, I wish we had glass to prevent bird collisions,'" Blank explains. "But when it was pointed out to me, I jumped on board. If you're going to build a building that shows people all the good things you can do, this really should be among them."

That set the team off on the kind of research that seems to characterize Living Building projects. The design team tasked Miller Hull Partnership architect Matt Kikosicki, who had experience with bird-friendly projects, to research the options. (LAS and Miller Hull are design partners on the project.) Kikosicki touched bases with Betuel, who in turn suggested that the team consult with Sheppard.

"We can try to get familiar with the specific issues that come up on our projects," Kikosicki says. "But it's really helpful to get together with experts and sort of synthesize their information."

The guru of bird collisions

Sheppard certainly fits the definition of an expert. For more than a decade, she's made reducing bird collision death her professional mission. Her experience as an ornithologist with a doctorate from Cornell and the former director of bird programs at Bronx Zoo give Sheppard credibility on the science. Her efforts at the American Bird Conservancy have elevated that organization's Bird Collisions Campaign into a national clearinghouse for research, advice and activism.

"I love birds and I like to solve problems, which is what makes this a perfect job for me," Sheppard says.

In 2009, Sheppard worked with the Powdermill Nature Reserve in Pennsylvania to construct a bird collision tunnel that would systematically test the way various species responded to different bird-friendly glass designs. That tunnel, together with a second one recently installed at the Bronx Zoo in

New York, have now tested products from 20 glass fabricators, according to Sheppard. They've found that as many as 94 percent of birds would fly toward a conventional window when given the choice between the conventional window, and one with ceramic patterns, or frits, on the outer pane of the window. (Lest you worry: The tunnels are fitted with transparent nets to protect the test subjects from smacking into the glass.)



A researcher prepares to release a small songbird into the American Bird Conservatory's bird-safe glass test tunnel in Pennsylvania. Photo by Pamela Curtain, Carnegie Museum,

Sheppard and her team also found that the patterns should follow a "two-by-four rule." To signal to birds that they should avoid the windows, the unobstructed view must be less than two inches high or less than four inches wide because that happens to be the width and height that most migratory songbirds view as a safe passage.

Sheppard advocates approaches that go beyond bird-safe glass. A 60-page Bird-Friendly Design guide published by the Conservancy suggests that architects mask windows with netting, grilles, shutters and screens where possible. The LEED Pilot Credit, which she helped author, restricts exterior lighting (lights often draw birds toward buildings), and includes a complex formula to lower

the “threat level” by discouraging uninterrupted walls of plain, unobstructed glass, especially on lower floors where trees are more likely to be reflected.

Now, a major focus for Sheppard and for allies at the Audubon Society is codes and legislation. In 2011, over the objection of some developers, San Francisco became the first city to adopt Bird Safe Building Standards.

“San Francisco hasn’t died [as a result of the new ordinance],” Sheppard quips. “They haven’t exactly had a slowdown in building.”

Ordinances or building standards are now in place in Cook County, Ill., San Jose, Calif., and the state of Minnesota, among other places. Federal legislation has been introduced by Sen. Cory Booker, D-N.J., and Rep. Mike Quigley, D-Ill.

Much of the legislation is modeled on the LEED Pilot Credit. For all practical purposes, the credit has become the most widely used standard for bird-safe design n jurisdictions without bird-friendly legislation. One example: the Kendeda Building.

“We did use the LEED pilot credit as a guideline,” Gassman says. “It is one of the few resources out there that suggests strategies for avoiding bird collisions.”

Bird safety not as difficult as expected

As it turns out, windows on the east face of the Kendeda Building had been designed to include exterior shades before bird-friendly features were even considered. After consulting with Beutel and Sheppard, however, the design team decided that curtain walls that will offer views of the Georgia Tech Eco-Commons to the west and of the building’s green roof toward the north provided ideal surfaces for bird protection.

Ultimately, Kikosicki stresses, the architects had to balance their bird-safe glass selection against other values. For one, there’s the LBC ban on toxic Red List materials. The manufacturers of one

product — a pane containing ultraviolet patterns visible to birds but not humans — “were not super-willing to disclose the ingredients.” The lack of transparency struck that option off the list.

For another, LBC’s Energy Petal requires extreme energy efficiency. For all practical purposes, that means three panes. So a bird-safe solution designed to be installed with an extra pane would have forced the Kendeda Building to require quadruple-glazed windows. That would have required custom fittings and much steeper costs.



This bird-safe window with a dot pattern will look out to the Kendeda Building’s green roof. PHOTO AT TOP OF STORY: From some angles, the dot pattern is barely visible. Photos by Ken Edelstein

Based on Sheppard’s recommendations, the team leaned anyway toward visible patterns, applied as frits, on the outer pane. They opted to purchase the window from Viracon, the nation’s largest architectural glass supplier.

Viracon also happened to be the first glass fabricator to be tested in Sheppard’s tunnel. According to Alissa Schmidt, technical resources manager for the Minnesota-based company, Viracon’s strategy

has been “to offer a bird friendly product that was readily available and affordable.”

So the company has focused on solving the bird-collision problem by silkscreening frit patterns onto the outer surface of the glazing that already are part of its product line. Because it’s difficult to separate out the silkscreening specified for bird safety from those purchased for other reasons, Viracon has a hard time quantifying its bird-friendly sales. But, Schmidt says, “we’ve seen the architectural community’s requests for bird-friendly products increase steadily in the nearly 10 years since we first had the American Bird Conservancy test our products.”

Sheppard’s tunnel tests found that dark gray horizontal bands were most effective at dissuaded birds. But the Kendeda Team opted for a gray dot pattern because — while slightly less effective in deterring birds from hitting the windows — it was more fitting aesthetically.

For Betuel, it’s a huge victory.

“There’s a glaring gap on this [buildings with bird-friendly design],” he says. “I don’t know why it is. I’m not sure if it’s that the products weren’t there or were difficult to source, or maybe they just didn’t have the knowledge. But a lot more products are becoming available now, and I think people are just becoming more aware of it. Hopefully, showing people that it can be done will get others to do it.”

After working together on the Kendeda Building, he, Sheppard and Kikosicki submitted a proposal for a session on bird-safe glass at the U.S, Green Building Council’s massive Greenbuild conference, which will be held this year in Atlanta.

The cause has a way of gaining momentum, says Gassman, who recently was given a new title as Lord Aeck Sargent’s director of sustainable design.

“I want it to be a bigger deal,” he says. “If it was up to me, the Living Building Challenge, to live up to its aspiration and its name, should make [bird safety] a mandatory part of certification.”

COMMENTS (1)

Josh Basher says:

November 2, 2019 at 11:28 am

The engineering that when into this building is amazing. Here is a “light” breakdown of the energy efficiency capabilities of the Kendeda Building: https://www.youtube.com/watch?v=4ddtz_LgiH0

MORE ARTICLES

List of awards for Kendeda Building continues to grow

3 project leaders on the impact of the Kendeda Building



Kendeda Building earns Living Building Challenge certification



A village of sticks overlooks the Kendeda Building

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About the ABC Rating System

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What is a Threat Factor?

It is difficult to objectively define what makes glass "bird-friendly." Although used frequently, the term 'bird-friendly' itself provides no specific guidance. Architects interested in designing a building that does not kill birds can select products for their insulation value, breaking strength, or a host of other characteristics, but until recently there was no system for specifying bird-friendly materials. Making analysis more difficult, the quality of being bird-friendly is more complex than a quality like insulation value because birds respond to the appearance of glass and this can vary dramatically for a single product as seen in the changing light of day, as well as under artificial light at night. Additional complexities such as IGU build, façade or freestanding installation, differing reflected environments and other factors make each situation unique. Contributing factors vary so much that an absolute measurement cannot be provided.

In 2010, experts from American Bird Conservancy and a team of architects interested in advancing the field of bird-friendly design developed the concept of Threat Factor (TF). This is a way to assign scores that provide a relative measure of how well materials with patterns of visual markers cause avoidance by birds in a standard, controlled test environment. These scores allow architects to use collision deterrence as a factor when designing buildings. The system also permits evaluation of products that can be applied to existing glass (retrofits). TFs also made it possible to create a credit for reducing bird collisions in the LEED rating system and have now begun to be included in legislation, like New York City's Local Law 15 of 2020.

Where Do Threat Factors Come From?

Ideally, Threat Factors could be derived from monitoring collisions on glass at a collection of diverse, existing buildings, replacing that glass with a product under review, continuing to

monitor to see whether collisions are reduced and calculating the reduction. Unfortunately, this type of data is very rare and this type of test would be very costly. It would also take years to acquire enough monitoring data to reliably detect a trend for a single product and, importantly, it would kill birds. ABC realized the need to create practical ways to evaluate glass. Initially, TFs were derived only from a *tunnel test (described below).* More recently, data from field trials and other types of testing have been factored in.

Assigning Threat Factors Using Tunnel Testing

In 2003, Martin Rössler and Thomas Zuna-Kratky (2004) created the first "tunnel" at the Hohenau-Ringelsdorf Biological Station (Austria), to test proposed solutions to bird collisions on freestanding noise barriers. ABC's tunnels, using a second-generation design (Rössler et al., 2007), followed in 2009 and 2021. Tunnel testing is a non-injurious, standardized binomial choice technique that uses wild songbirds to determine the relative effectiveness of different patterns of visual markers at deterring bird collisions. In the U.S., tunnel testing takes place at American Bird Conservancy's tunnel at either the Carnegie Museum of Natural History's Powdermill Avian Research Center or at Washington College's Foreman's Branch Bird Observatory .

In a test flight, a bird flies down a completely dark space, the 'tunnel' (Figure 1), toward light at the far end, where side-by-side panels of glass appear to offer exit routes (Figure 2). One of these panes of glass is clear, unmarked glass (the control, invisible to the bird) and the other has the pattern of visual markers under evaluation (the test pane). A net ensures that the bird is safely stopped before it can hit the glass. After one trial, the bird is immediately released. When few birds fly to the patterned glass, we believe that they see and are avoiding the visual markers. For a detailed description of the Powdermill and Hohenau tunnels, see Sheppard (2019) and Rössler et al. (2007).



Figure 1. Test Tunnel at Foreman's Branch

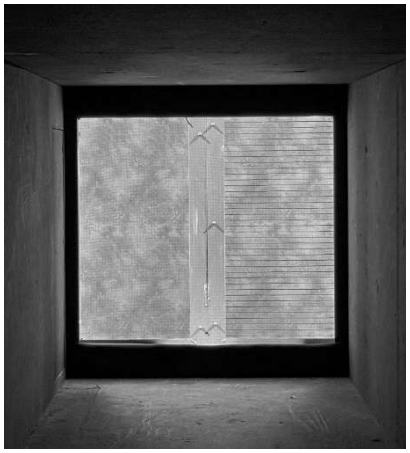


Figure 2. View of glass samples

Specimen Performance Index (SPI) of a material is calculated by flying at least 80 individual birds down the tunnel and recording the percent that fly toward the test pane. For example, suppose 80 birds flew down the tunnel, with 20 flying toward the test pattern and 60 toward the control.

25% (20/80) of the birds flew toward the test pattern and it would have SPI of 25. If there is no additional information, for example, from a field trial, then the TF is equal to the SPI.

Important considerations

- SPIs and TFs *do not* warranty the actual percent reduction in collisions to be expected when a product is installed on a building. In fact, the same product may perform better or worse due to facade orientation in the same building, façade detail creating traps or channels, habitat reflected, whether the glass is free-standing and other variables. Threat Factors are an index, measuring the relative response to different patterns and different glass builds by songbirds flown in the tunnel. However, where monitoring data on tunnel-tested products are available, they confirm that products with lower threat factors yield fewer collisions. **ABC defines "bird-friendly" materials as having a threat factor ≤ 30, corresponding to a conservative estimated reduction of collisions of at least 50% under real world conditions.**

- The lower the Threat Factor, the more effective the tested material will be at reducing collisions. This has been confirmed when data is available. However, the relationship between TF score and effectiveness does not appear to be linear, so one cannot say that a pattern with TF=15 is twice as effective as a pattern with TF=30.

- Strong reflections can reduce pattern effectiveness by obscuring the visual markers during part or all of the day, if the pattern is on an inside surface of the glass. Reflections vary with insolation and with the angle of view, from the strongest reflections at acute angles to the weakest reflections when glass is viewed head on (Figure 3)

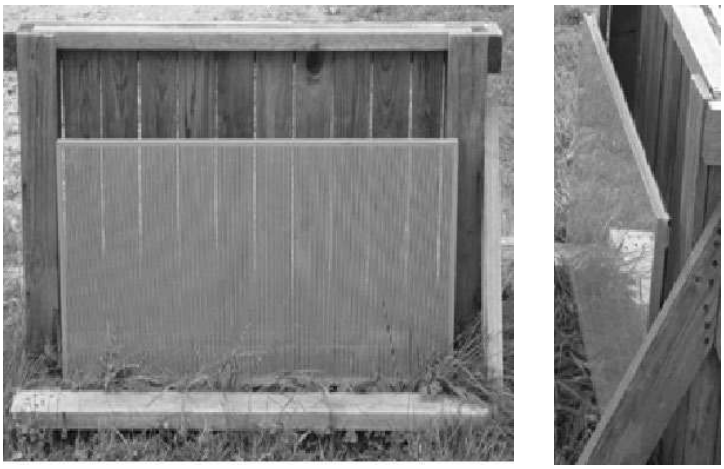


Figure 3: A single piece of glass with frit on surface 2, viewed head on (left) and from the side (right): The reflection is much stronger at an acute angle than it is head on. This glass has a surface reflectivity < 14%. However, for a bird to view this glass at an angle where there is a dangerous reflection, it would be flying almost parallel to the glass surface, where a collision would be unlikely to cause injury.

- ABC's tunnel test cannot replicate the range of possible reflections on a glass sample, so our tests model situations where a pattern is visible against a competing view. In the tunnel, birds see visual markers against a complex background (seen in figure 2), modeling situations where either the glass has only a moderate reflection or when birds can see through the glass to a landscape beyond. While it might seem at first that "reflection" and "see-through" conditions are quite different, in this context they are similar. In figure 4a, below, we cannot determine whether the image is a photo of a tree, a tree seen through a window, or the reflection of a tree. With the information in 4b, showing mullions, a crack, and right angles, we know glass is involved, but only with the information in figure 4c can we confirm that the image is a reflection and that we are not looking out the window at trees.



Figure 4a.



4b.



4c.

- ABC does not test materials with greater than 15% reflection (VLR) at the exterior surface of the glass, unless the visual markers are on the outside surface, or our BirdVis app (see appendix II) shows that there is sufficient contrast for markers to show through reflections.

- Because reflections on glass are both site and product specific, reflections should be considered early in the design process. Recommended design phase analysis ideally involves samples of glass viewed on the project site from a variety of angles, at different times of day, and with all potential site-specific reflections taken into consideration.

Spacing of Visual Markers

Where early recommendations, based on research by Klem (1990) and Rössler et al. (2007), showed that horizontal lines spaced 2" (5cm) apart and vertical lines spaced 4" (10cm) apart significantly reduced collisions, subsequent monitoring showed that the 4" spacing does not stop collisions by the smallest birds, especially hummingbirds. The spacing guideline for the Prescriptive Rating Option assigns a lower score when there is 2" (5 cm) spacing between the pattern's visual markers vertically and horizontally and a higher score for patterns with 4" (10 cm) horizontal spacing. Two inch (5 cm) spacing for two-dimensional patterns on glass or window film is now typically recommended in Canada (Canadian Standard A460) and increasingly in the United States. Thus, what was once the '2x4 rule' is now the '2x2 rule'. However, 2x4" spacing has been demonstrated to reduce collisions significantly and materials based on that guideline can still receive a 'bird-friendly' TF rating.

Visual Acuity

For a pattern of visual markers on glass or other materials to successfully deter bird collisions, birds must be able to perceive it in time to change course. The pattern of visual markers must be of an appropriate size and spacing and must be distinguishable from the both glass and any reflections or the view through the glass (e.g., habitat, sky, water, a potential flight path, etc.). We have adopted 9'-9' ½" (3 meters) as the standard viewing distance from which birds must be able to detect the pattern, following Ros et al. (2017).

Our instinct is to use human vision as a proxy for what birds can see. However, birds can see more colors and even perceive the earth's magnetic field, while humans have much better visual acuity. 'Visual acuity', the ability to resolve spatial features depends on the size of the eye and the number of photoreceptors in the retina. Songbird eyes are much smaller than human eyes. Because of this, birds, particularly small birds like songbirds, have very poor visual acuity in comparison to humans. Therefore, a pattern that appears quite visible to us may not be apparent at all to birds (Caves, Brandley and Johnsen, 2018).

Ultraviolet Patterns

Products with UV patterns should be considered carefully for some applications: Materials with ultra-violet patterns will vary in effectiveness with the amount of UV light present. This means that when the UV index is low – under low light conditions in early morning or evening or if the glass is shaded, or when it is overcast – UV patterns will be less visible to birds. In addition, not all types of birds can see UV. For example, songbirds can see UV, raptors and pigeons cannot.

Assigning Threat Factors Without a Tunnel Test

Not all materials need to be tunnel tested, specifically materials that are similar to others previously tested. ABC partners with the Bird-Safe Buildings Alliance (BSBA), a group of architects experienced in bird-friendly design, conservation biologists, and others with collisions expertise, to provide TFs for materials similar to those already rated. These ratings are very conservative: the rating assigned is the maximum expected TF; lower ratings might be obtainable through actual tunnel testing.

TFs can be assigned by review, instead of by tunnel test, to products that: a) were tested using other, peer-reviewed protocols that ABC and BSBA have determined to be equivalent or translatable to tunnel testing scores, b) were studied by scientists or experienced building collision monitors with a documented reduction in collisions of at least 50%, or c) comply with ABC's Prescriptive Rating Option (Appendix III). The Prescriptive Rating Option describes only a subset of materials that can be rated by other methods.

Appendix I. Definitions

Acid Etch: the use of hydrofluoric acid on glass to create translucent visual markers with texture and a 'frosted' appearance.

Exterior Visible Light Reflection (VLR): Net Exterior (measured at surface 1) reflection of complete glass build, including any coatings, (for the purpose of the prescriptive rating option, the VLR excludes visual markers)

Gloss reading of markers (60°): Please see ASTM D523 Standard Test Method for Specular Gloss

Opaque: Visible Light Transmission (VLT) = 0

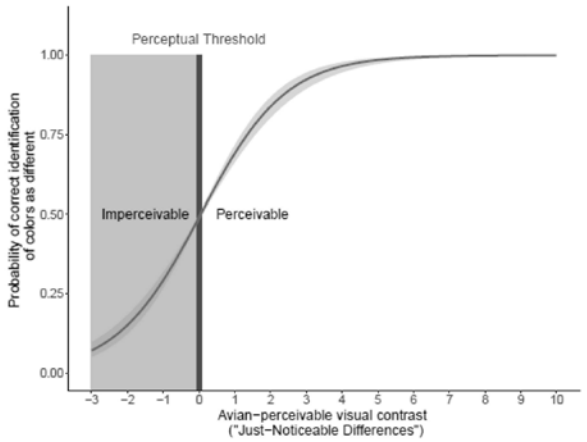
Pattern: Spatial arrangement and dimensions of visual markers on glass.

Visual Contrast: A difference in visual appearance of two surfaces sufficient for birds to distinguish between the two surfaces.

Appendix II. The BirdVis App: Avian Visual Contrast Levels

Because human perception is unreliable for evaluating what is sufficiently visible to birds, the Bird-safe Buildings Alliance contracted for the creation of an app, based on properties of the avian retina and studies of avian visual acuity. The BirdVis app (3.140.67.204:3838 Luro, 2021) calculates contrast level between the pattern of visual markers and glass (visual contrast level or VCL) and also displays pattern resolution.

Visual contrast is a difference in visual appearance sufficient to distinguish between two surfaces or two areas on the same surface. BirdVis uses the spectral reflectance of glass and associated pattern of visual markers, as well as data on avian eyes to model visibility of a pattern applied or integral to a particular glass. Visual Contrast Levels (VCL) are quantitative estimates of how visible (to birds) a pattern is against the associated glass.



BirdVis sets an avian 'just perceivable' visual contrast level at 0. This means a pattern/glass combination with a VCL value > 0 is determined to be sufficiently visible to birds (perceivable), while VCL values ≤ 0 indicate the pattern will likely not be seen against the glass by birds (unperceivable). Contrast values much greater than 0 (e.g., 5 and above) are predicted to be highly visible to birds.

The BirdVis model incorporates 4 main variables:

1) the avian visual system (bird photoreceptor sensitivities + simulated "neural noise" for each photoreceptor type),
2) the reflectance of glass and pattern samples,
3) the background against which the glass sample/pattern is viewed (this is ignored in the current model; it doesn't change the model estimates much because of visual adaptation to backgrounds), and
4) the types of light illuminating the glass and glass pattern (illuminants).

The model uses three illuminants: Midday sunlight (or Daylight, "D65, the international CIE-standard illuminant for average midday sunlight. cf Schanda, 2007), Blue Sky, and Forest Shade (Endler, 1993). The calculated avian visual contrast values are the mean of visual models across a handful of passerine species using all three illuminants (every bird visual system + illuminant combination is modeled). We can eventually change the illuminant using any light source as long as we can get absolute spectral irradiance measurements for it, meaning we could model how the glass appears at different locations and times of day.

Appendix III.
Assigning Threat Factors via Prescriptive Rating Option

All materials with assigned Threat Factors can be found here

Prescriptive Criteria for Glass with Opaque, non-metallic 2" x 2" Patterns

Bird-friendly glass assemblies that meet the following requirements are assigned a

Threat Factor of 20.

The glass assembly must have **all three** of the following characteristics:

I.

a. Surface one patterns only: No limit on VLR
    i. Acid etch
        1. Clear, low-iron, or tinted glass
        2. Gloss reading of etch markers (60°) ≤ 6

    or

    ii. Opaque frit or other opaque, non-metallic marker
        1. Clear or low-iron glass

OR

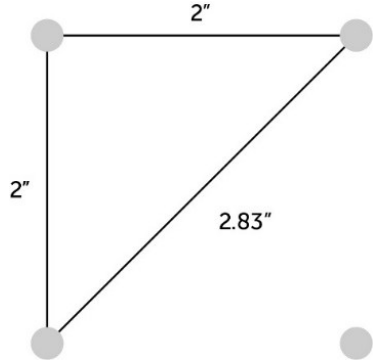
b. Surface two patterns only: VLR must be ≤ 15%
    i. Opaque frit or other opaque, non-metallic marker
        1. Clear or low-iron glass

II. As viewed from surface 1, all low emissivity (low-E) coatings must be behind pattern.

III. A pattern of visual markers comprising one of the following marker types or a combination:

b. Continuous solid lines at least 1/8" wide (~3mm), nowhere more than 2" apart, measured edge to edge.

c. Circular, square, or irregular solid shapes that are nowhere more than 2" from the nearest shape, measured horizontally or vertically, (edge to edge) and no more than 2.83" diagonally to the nearest shape (see diagram below). Each shape must have a minimum area of ≥ 0.049 in^2, which corresponds approximately with circles of diameter ¼" (~6mm).



Prescriptive Criteria for Glass with Opaque, 2” x 4” Patterns

Bird-friendly glass assemblies that meet the following requirements are assigned a

Threat Factor of 25.

The glass assembly must have **all three** of the following characteristics:

I.

a. Surface one patterns only: No limit on VLR
    i. Acid etch
        1. Clear, low-iron, or tinted glass
        2. Gloss reading of etch markers (60°) ≤ 6

    or

    ii. Opaque frit or other non-metallic, opaque marker
        1. Clear or low-iron glass

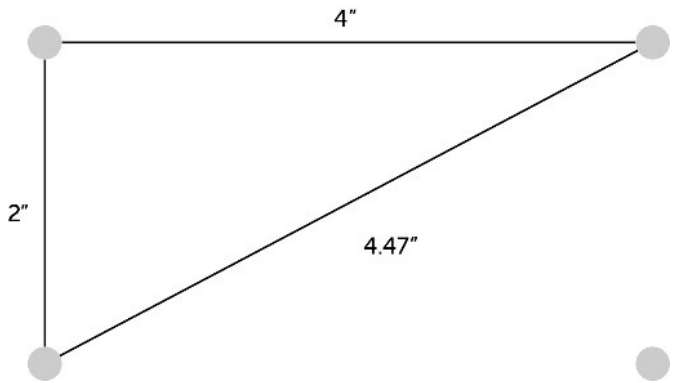
OR

b. Surface two patterns only: VLR must be ≤ 15%
    i. Opaque frit or other non-metallic, opaque marker
        1. Clear or low-iron glass

II. As viewed from surface one, all low emissivity (low-E) coatings must be behind pattern.

III. A pattern of visual markers comprising one of the following marker types or a combination:

a. Continuous solid lines at least 1/8” wide (~3mm), nowhere more than 2” apart for horizontal or angled lines, 4” for vertical lines, measured edge to edge.
b. Circular, square, or irregular solid shapes that are nowhere more than 2” from the nearest shape vertically and nowhere more than 4” from the nearest shape horizontally, or 4.47” to the nearest shape diagonally, measured edge to edge (see diagram below). Each shape must have an area of ≥ 0.049 in^2, which corresponds approximately with circles of diameter ¼” (~6mm).



Prescriptive Criteria for Glass with Opaque < 2" Patterns

Bird-friendly glass assemblies that meet the following requirements are assigned a

Threat Factor of 25.

The glass assembly must have **all three** of the following characteristics:

I.

a. Surface one patterns only: No limit on VLR
   i. Acid etch
      1. Clear, low-iron, or tinted glass
      2. Gloss reading of etch markers (60°) ≤ 6

   or

   ii. Opaque frit or other opaque, non-metallic marker
      1. Clear or low-iron glass

OR

b. Surface two patterns only: VLR must be ≤ 15%
   i. Opaque frit or other opaque, non-metallic markers
      1. Clear or low-iron glass

II. As viewed from surface one, all low emissivity (low-E) coatings must be behind pattern.

III. A pattern of visual markers comprising one of the following elements or a combination:

a. Continuous solid lines at least ¼" wide and spacing equivalent to line width, measured edge to edge, up to < 2".
b. Circular, square, or irregular, solid shapes with spacing between shapes no less than diameter of pattern's visual markers and no more than 2", measured edge to edge. Each shape must have a minimum area of ≥ 0.049 in^2, which corresponds approximately with circles of diameter ¼" (~6mm).

Prescriptive Criteria for Façade Materials without Patterns

-including Spandrel Glass-

Glass builds and Façade Materials that meet the following requirements are assigned a

Threat Factor of 25

I. Surface one is continuous acid-etch with a gloss reading (60°) ≤ 16.

II. Surface is stainless steel, ASTM finish 2B or 4.

References

Cassey P, Honza M, Grim T, & Hauber ME. 2008. The modelling of avian visual perception predicts behavioural rejection responses to foreign egg colours. Biology Letters 4(5):515-7. https://doi.org/10.1098/rsbl.2008.0279

Caves EM, Brandley NC, Johnsen S. 2018. Visual acuity and the evolution of signals. Trends in Ecology & Evolution 33(5):358-72. https://doi.org/10.1016/j.tree.2018.03.00

Caves, Eleanor M. and Sönke Johnsen. 2017. AcuityView: An R package for portraying the effects of visual acuity on scenes observed by an animal. Methods in Ecology and Evolution 9(3):793-7. https://doi.org/10.1111/2041-210X.12911

Chadwick AC, Kentridge RW. 2015. The perception of gloss: A review. Vision research 109:221-35. https://doi.org/10.1016/j.visres.2014.10.026

Endler JA. The color of light in forests and its implications. 1993. Ecological monographs 63(1):1-27. https://doi.org/10.2307/2937121.

Luro, Alec B. 2021. BirdVis 1.0.0. Bird-Safe Buildings Alliance. http://3.140.67.204:3838/.

Luro AB, Fernández-Juricic E, Baumhardt P, Hauber ME. Visual acuity and egg spatial chromatic contrast predict egg rejection behavior of American robins. 2020. Journal of Experimental Biology 223(20):jeb229609. https://doi.org/10.1242/jeb.229609

Ros IG, Bhagavatula PS, Lin HT, Biewener AA. 2017. Rules to fly by: pigeons navigating horizontal obstacles limit steering by selecting gaps most aligned to their flight direction. Interface Focus 7(1):20160093. https://doi.org/10.1098/rsfs.2016.0093

Thomas RJ, Kelly DJ, Goodship NM. 2004. Eye design in birds and visual constraints on behavior. Ornitologia Neotropical 15(suppl):243-50.

Schanda, J. (Ed.). 2007. Colorimetry: understanding the CIE system. John Wiley & Sons. Hoboken, New Jersey, USA.

RB324.7-24 – Staff Summary

Proponent: William Penniman, representing Northern Virginia Bird Alliance; Sonal Shah, Northern Virginia, representing Northern Virginia Bird Alliance; Thomas Blackburn, Northern Virginia, representing Northern Virginia Bird Alliance

Brief Description: Adds requirements for bird-friendly design and construction to the VRC.

STUDY GROUP OR SUB-WORKGROUP INFORMATION

N/A

GENERAL STAKEHOLDER WORKGROUP INFORMATION

Third GSW Meeting 1/6/2026

Support: None

Opposition: Steve Shapiro, Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA).

Discussion:

Sonal S (Northern Virginia Bird Alliance) provided an overview of the proposal which is the residential companion to proposal B2403.6-24.

a. **Steve S** proclaimed that he had the same opposition as proposal B2403.6-24.

DHCD Staff Note:

The VCC companion proposal B2403.6-24 was also discussed at the same GSW meeting and received a Non-Consensus recommendation. The excerpt from the January 6, 2026 meeting summary pertaining to B2403.6-24 is provided below.

January 6, 2026, GSW Meeting Summary Excerpt

Support: None

Opposition: Steve Shapiro, Virginia Apartment Management Association, Apartment & Office Building Association of Metropolitan Washington (AOBA/VAMA); Dan Willham, Fairfax County and Virginia Building and Code Officials Association (VBCOA); Andrew Clark, Home Builders Association of Virginia (HBAV); Rick Hinson, American Council of Engineering Companies (ACEC); and Paul Messplay, Hanover County.

Discussion:

Tom Blackburn provided an overview of the proposal.

i. **Sonal Shah** advised that as availability and awareness increases for these products, the cost will be driven down.
ii. **Steve Shapiro** commented that these requirements are beyond the intent of the code to provide the minimum for health, safety, and welfare. The costs are also enormous. Also, it is not known if the reference standard being proposed has been reviewed to see if it meets the ICC requirements for reference standards.
iii. **Dan Willham** agreed with **Steve Shapiro** that this proposal is outside of the scope of the VCC.
iv. **Andrew Clark** alerted the group that the lead time to get some of these products is eight to ten months.