12/16/21 6:25 pm

Commenter: Oleg Bulshteyn

Better sound insulation is required for multifamily residential buildings!

According to National Multifamily Housing Council (www.nmhc.org), noise has been identified as a major issue by residents of multifamily residential buildings. In addition, according to Alexandria, VA Office of Housing, noise transmission is one of the biggest issues for renters in
multifamily buildings. The problem is worst in buildings constructed of wood above concrete podiums, and better in steel and concrete high rises. Further, thousands of resident reviews are available on the internet citing poor sound insulation of multifamily residential buildings including those recently constructed so it appears that the existing building codes/construction techniques do not result in the adequate level of the sound insulation in multifamily buildings; finally, when the residents move into brand new multifamily residential buildings there is no way for the residents to know what the building sound insulation will be.

12/22/21 8:32 am

Commenter: Samantha Ahdoot

Update Building Codes to Protect Health of Virginians

December 22, 2021

To: Board of Housing and Community Development
c/o Kyle Flanders, Department of Community Development

From: Virginia Clinicians for Climate Action

Re: Comments on NOIRA for 2021 Cycle to Update the Building Code

These comments are submitted on behalf of Virginia Clinicians for Climate Action (VCCA). VCCA was founded in 2017 in order to bring the clinician voice in support of local and statewide climate policy solutions that protect the health of our patients and communities in the Commonwealth. As clinicians, we are concerned about the building code as it relates to the impact of home efficiency, air quality and harmful exposures on the health of Virginians.

The health benefits of strong building codes are significant.1 Numerous scientific studies have demonstrated that housing renovations that improve ventilation, insulation, and heating/ cooling equipment result in reduced pollutants, better controlled indoor temperature and moisture, and avoidance of building materials that contain hazardous substances. Increased insulation protects against cold or heat-related deaths in areas that experience extreme temperatures.2 Warmer, drier indoor air protects against symptoms of respiratory disease including asthma and Chronic Obstructive Pulmonary Disease.3 Upgraded heating and ventilation systems can limit exposure to particulates, gaseous pollutants, and mold. These improvements can decrease symptoms of respiratory and heart disease and reduce risk of cancer.2

Moreover, improved indoor air quality can particularly benefit the health outcomes of low-income populations.4 A study conducted in 2014 found that low-income, multi-family households living in green buildings experienced fewer symptoms pertaining to illness. They also observed a significant improvement in the health of individuals who moved into green housing and significant decreases in exposure to harmful indoor air pollutants.5 Furthermore, energy-efficient homes can improve the well-being of Virginians through decreasing the financial burden associated with energy costs.

New buildings and updated older buildings will be occupied for years to come. Thus, the health, energy, and cost savings from energy-efficient homes have a long-term positive impact on Virginians' health that will accrue over decades. Structural efficiency improvements are much less costly to install during initial construction. Missing that opportunity reduces the chances that such improvements will ever be made or the health benefits realized by occupants. Energy production and emissions also contribute to air pollution and climate change, both of which are associated with a multitude of direct and indirect health consequences.6

For the reasons stated above, VCCA supports the adoption of the full 2021 IECC without any weakening amendments in order to best serve the public interest as prescribed by Virginia Code Section 36.99A. Section 36-99A of the Virginia Code prescribes "The provisions of the Building Code and modifications thereof shall be such as to protect the health, safety and welfare of the residents of the Commonwealth…." In order to achieve optimal health benefits to current and future Virginians, the review process should begin with the 2021 IECC and conclude with adoption of standards at least as stringent as those in this IECC.

Adopting such standards would perform the important function of keeping Virginia's building code "in sync with the national model codes," except where more stringent standards are feasible. Doing so would also be consistent with H2227, which requires consideration of standards "at least as stringent" as those in the IECC and even more stringent when the benefits to residents and the public over time exceed the incremental cost of construction.

VCCA urges the Board to expeditiously adopt and implement updated building codes that are at least as stringent as the 2021 IECC. Doing so will best protect the health of Virginians for decades to come.

Respectfully submitted,

Samantha Ahdoot, MD

Chair, Virginia Clinicians for Climate Action

1 Sharpe RA, Taylor T, Fleming LE, Morrissey K, Morris G, Wigglesworth R. Making the Case for "Whole System" Approaches: Integrating Public Health and Housing. Int J Environ Res Public Health. 2018;15(11):2345. Published 2018 Oct 24. doi:10.3390/ijerph15112345

2 Wilson J, Jacobs D, Reddy A, Tohn E, Cohen J, Jacobsohn E. Home rx: The health benefits of home performance. National Center for Healthy Housing, U.S. Department of Energy. 2016;DOE/EE-1505 7861

3 E4The Future I. Occupant health benefits of residential energy efficiency. E4The Future, Inc. 2016

4 Breysse J, Jacobs DE, Weber W, et al. Health outcomes and green renovation of affordable housing. Public Health Rep. 2011;126 Suppl 1(Suppl 1):64-75. doi:10.1177/00333549111260S110

5 Colton MD, MacNaughton P, Vallarino J, et al. Indoor air quality in green vs conventional multifamily low-income housing. Environmental science & technology. 2014;48(14):7833-7841. http://dx.doi.org/10.1021/es501489u. doi: 10.1021/es501489u.

6 Romanello M, McGushin A, Di Napoli C, et al. The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future. Lancet. 2021 Oct 30;398(10311):1619-1662. doi: 10.1016/S0140-6736(21)01787-6. Epub 2021 Oct 20. Erratum in: Lancet. 2021 Dec 11;398(10317):2148. PMID: 34687662.

December 22, 2021

To: Virginia Board of Housing and Community Development
c/o Kyle Flanders, Virginia Department of Housing and Community Development

From: Virginia Chapter of the Sierra Club;
Faith Alliance for Climate Solutions;
Climate Action Alliance of the Valley; and
Climate & Clean Energy Working Group, Virginia Grassroots Coalition

Re: Comments on NOIRA for 2021 Cycle to Update the Building Code

These comments are submitted on behalf of the Virginia Chapter of the Sierra Club, Faith Alliance for Climate Solutions, Climate Action Alliance for the Valley, and the Climate & Clean Energy Working Group, Virginia Grassroots Coalition.[1] Collectively, these organizations have more than 30,000 members who are residents of Virginia.

NOIRA Published November 22, 2021

The Board's NOIRA published November 22, 2021, seeks comments on the BHCD's proceedings to update Virginia's Uniform Statewide Building Code and related codes ("USBC") to incorporate the 2021 International Construction Code (ICC), including the 2021 International Energy Conservation Code. In describing its purpose, the NOIRA states:

> The 2021 editions of the International Codes are now completed and available from ICC. The use of the newest available model codes and standards in the USBC assures that the statutory mandate is met to base the regulation on the latest editions of nationally recognized model codes to assure the protection of the health, safety and welfare of the residents of Virginia and that buildings and structures are constructed and maintained at the least possible cost.[2]

---

[1] **Virginia Chapter of the Sierra Club** has over 20,000 members. The Sierra Club is a non-profit, membership organization dedicated to exploring, enjoying and protecting wild places; to promoting the responsible use of the Earth's resources and ecosystems; to educating and enlisting humanity to protect and restore the quality of the natural and human environment; and to using all lawful means to carry out those objectives.
Faith Alliance for Climate Solutions (FACS) is a non-profit organization with more than 185 faith communities and 3,600 faith-based activists in Virginia whose mission is to develop local solutions to climate change.
Climate Action Alliance of the Valley (CAAV) is an organization representing at least 1,000 residents of the Shenandoah Valley. CAAV's mission is to limit the impact of humans on Earth's climate and minimize the effects of inevitable climate change in order to protect the future for Earth and its inhabitants.
Virginia Grass Roots Coalition includes over 50 grass roots organizations with over 10,000 members. https://reston-data-visualization-fairfaxcountygis.hub.arcgis.com/apps/reston-zoning-activity-data-hub/explore

[2] The NOIRA can be found at https://townhall.virginia.gov/L/viewstage.cfm?stageid=9475 . The Board's notice of the January 10, 2021 public hearing describes its purpose as "a public hearing to receive comments on regulations prior to the adoption of proposed regulations. Another public hearing will be held after the adoption of proposed regulations." https://townhall.virginia.gov/L/ViewMeeting.cfm?MeetingID=34484

The NOIRA also recognizes: "As the basis for Virginia's building code it is important to stay in sync with the national model codes."

We agree with these statements, particularly as they relate to energy conservation measures published, in 2020, by the ICC after careful and lengthy deliberations. Section 36-99A of the Virginia Code has long prescribed that the purposes of the USBC are to protect the public and implement recognized standards of energy conservation and water conservation:

> "The provisions of the Building Code and modifications thereof shall be such as *to protect the health, safety and welfare of the residents of the Commonwealth*, provided that buildings and structures should be permitted to be constructed, rehabilitated and maintained at the least possible cost *consistent with recognized standards of health, safety, energy conservation and water conservation*…."

Although the NOIRA does not mention it, legislation (H2227), enacted by the General Assembly earlier in 2021, supplements the pre-existing law's commitment to protecting residents and the public "consistent with recognized standards of … energy conservation" by endorsing adoption of energy standards "at least as stringent as" the latest IECC when the benefits "over time" to residents and the public exceed the incremental costs of construction.

Virginia Should Adopt Energy Standards At Least As Stringent as the 2021 IECC

Virginia should adopt the full 2021 IECC without any weakening amendments. More stringent standards may be proposed and appropriate in some instances. Adopting such standards would perform the important function of keeping Virginia's building code "in sync with the national model codes," except where more stringent standards are feasible. Doing so would be consistent with H2227, which requires consideration of standards "at least as stringent" as those in the IECC and even more stringent when the benefits to residents and the public over time exceed the incremental cost of construction.

It is clear that full implementation of the IECC meets the benefit/cost standards in H2227 and serves the public interest as prescribed by Virginia Code Section 36.99A. In this regard,

- The ICC process that produced the IECC was a multi-year effort that carefully vetted the amendments that were eventually adopted.
- DOE and the Pacific Northwest National Laboratory (PNNL) have already published findings demonstrating that the net savings to Virginia residents and to the public from implementing the full 2021 IECC exceed the incremental costs of construction. https://www.energycodes.gov/technical-assistance/publications?page=29
- DOE/PNNL has reached the same conclusion on a national basis. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-31437.pdf
- DOE/PNNL has previously found that earlier IECC updates dated 2012, 2015 and 2018 produced savings and benefits greater than construction costs.

Given Virginia law and independent analysis from DOE/PNNL, the Board should begin the 2021 building code regulatory process with presumed implementation of the full IECC. It should not start from a so-called "Base Document" which would carry forward past weakening amendments to the 2018 IECC (and earlier IECCs). Although some work group members blocked full adoption of the 2018 IECC (as well as the 2015 and 2012 IECCs) by withholding their consent in the work group "consensus" process, that blocking action should not be allowed to happen again. The review process should begin with the 2021 IECC and conclude with adoption of standards at least as stringent as those in the IECC.

The Board must recognize that new buildings and rehabilitated older buildings are likely to be occupied for decades – 50-100 years or even longer. Energy and cost savings to residents from energy efficient dwellings will last for decades, and those savings will extend to future occupants, not just initial occupants. Health benefits will accrue to residents and the public. Reductions in energy usage will lower air and water pollution associated with production and combustion of fossil fuels. Greater efficiency will also reduce environmental harm, as well as utility rates, attributable to minimization of construction and operation of new generation and transmission facilities. Further, structural efficiency measures (walls, air infiltration, etc.) are much less costly to install during initial construction when walls are open and workers are already present. Missing that cost-cutting opportunity reduces the chances that such improvements will ever be made.

Conclusion

The undersigned urge the Board to expeditiously adopt and implement updated building codes that are at least as stringent as the 2021 IECC. Doing so will best protect residents and the public for decades to come.

Respectfully submitted,

William H. Penniman

Kate Addleson, Director
William Penniman, Sustainability Chair
Virginia Chapter of the Sierra Club
100 W Franklin St, Mezzanine
Richmond, VA 23220
Phone: 804-225-9113

Eric Goplerud, Chair
Faith Alliance for Climate Solutions

Jo Anne St. Clair, Chair
Climate Action Alliance of the Valley

Sharon Shutler, Co-Chair
Climate & Clean Energy Working Group, Virginia Grassroots Coalition

Submitted Via Email

December 22, 2021

Cindy Davis
Director of Building and Fire Regulations
Virginia Department of Housing and Community Development
600 East Main Street, Suite #300
Richmond, VA 23219

RE: RECA Comments Supporting the Adoption of the 2021 International Energy Conservation Code for Residential and Commercial Construction in Virginia

Dear Director Davis,

The Responsible Energy Codes Alliance submits these comments in response to the Notice of Intended Regulatory Action related to the update of Virginia's Uniform Statewide Building Code (USBC) published in the November 22, 2021 Virginia Register. We support the efforts of the Department of Housing and Community Development (DHCD) to update the USBC and **we recommend the full adoption of the 2021 International Energy Conservation Code (*IECC*) for residential and commercial buildings.** The 2021 version of the *IECC* is a clear and substantial improvement over the 2018 version of the *IECC* and will provide a range of energy efficiency, comfort, resiliency, and environmental benefits for the owners and occupants of buildings in Virginia.

The need for decisive action to reduce energy demands and the production of greenhouse gases is clearer than ever before. In the 2021 Special Session, the Virginia General Assembly directed the Board of Housing and Community Development to "consider adopting Building Code standards that are at least as stringent as those contained in the new version of the *IECC*," including "potential energy savings and air quality benefits over time compared to the cost of initial construction."[1] Buildings are a large source of energy use and emissions, and the 2021 *IECC* provides a solution focused on improving the energy performance of buildings that will not only save money and promote local job creation but will also help Virginia achieve its greenhouse gas reduction goals.

[1] *See* 2021 VA Acts ch. 425.

Energy and Cost Savings

The *IECC* is the most widely adopted model energy code for residential and commercial construction, and earlier versions have been adopted in Virginia and nearly every state that has a statewide energy code. For the last fifteen years, the *IECC* has improved in efficiency with every new edition, providing straightforward energy and cost savings for the owners of homes and commercial buildings and providing an important policy tool for state and local governments to achieve energy efficiency and carbon reduction goals.

The current energy conservation requirements in the USBC are based on the 2018 *IECC*, but several weakening amendments were also adopted during the last code review cycle that leave cost-effective energy savings on the table. Eliminating these weakening amendments and adopting the new 2021 *IECC* presents an important opportunity for Virginia to provide leadership by upgrading to the most current version of the energy code, while capturing significant additional reductions in energy use and emissions and providing long-term benefits for the owners of homes and commercial buildings.

In accordance with federal law, the U.S. Department of Energy (DOE) analyzes and identifies energy cost savings expected to be generated by each new edition of the *IECC* for residential construction and by *ASHRAE* Standard 90.1 for commercial construction. (Standard 90.1 is incorporated as a compliance option in the commercial chapter of the *IECC*, and the energy savings figures for the *IECC*-Commercial Provisions and Standard 90.1 are typically similar.) To assist states in the consideration of the most recent model codes, DOE publishes state-specific energy savings and cost-effectiveness analyses for each state. As indicated in the summary table of DOE findings below, the owners and occupants of both residential and commercial buildings in Virginia stand to benefit from substantial energy cost savings with the adoption of the most recent editions of the model codes. A complete copy of both analyses is attached to these comments.

Residential[2]			Commercial[3]		
Residential Model Code	Energy Cost Savings over Current VA USBC	Life Cycle Cost Savings over Current VA USBC	Commercial Model Code	Energy Cost Savings over Current VA USBC	Avg Life Cycle Cost Savings over Current VA USBC
2021 *IECC*	**17.9%**	**$8,376**	***ASHRAE* Std. 90.1-2019**	**1.6-7.4%**	**$3.18/sq.ft.**

State-Specific Weakening Amendments

As noted earlier, in the most recent update to the USBC, several state-specific weakening amendments were adopted, leaving the statewide code short of its full potential for energy and cost savings. While some of these amendments were the result of compromises that allowed Virginia stakeholders additional time to work up to the full model code efficiency levels, we recommend that weakening amendments be phased out so that Virginia can catch up with the national model codes.

It is our understanding that the Board will use the 2021 *IECC* as the reference point for this code update, and we encourage the Board to carefully review and analyze all current state-specific amendments in order to determine whether they continue to be necessary, and whether they are consistent with Virginia's policy objectives. Although RECA will submit code change proposals via CDPAccess to eliminate state-specific amendments, as a preliminary matter, we offer here the following brief comments on a few current state-specific amendments to the USBC that weaken the code and should be eliminated so that the owners of Virginia homes and commercial buildings can enjoy the full benefits of the latest model energy codes:

- **Air Leakage Testing (Section R402.4.1.2)**. In the 2018 update, VA required blower door testing in all new residential buildings at ≤5 ACH50, which was a substantial improvement over Virginia's previous codes, but still weaker than the full 2018 *IECC* requirement of ≤3 ACH50. The 2021 *IECC* requires new homes to be tested to ≤3.0 ACH50, but it provides several new exceptions for smaller dwelling units and

[2] *See* U.S. Dep't of Energy, *Cost-Effectiveness of the 2021 IECC for Residential Buildings in Virginia*, at ii (July 2021), available at https://www.energycodes.gov/sites/default/files/2021-07/VirginiaResidentialCostEffectiveness_2021_0.pdf.

[3] *See* U.S. Dep't of Energy, *Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Virginia, at 3* (July 2021), available at https://www.energycodes.gov/sites/default/files/2021-07/Cost-effectiveness_of_*ASHRAE*_Standard_90-1-2019-Virginia.pdf.

multifamily buildings that we believe will allow additional flexibility to help homebuilders achieve the improved efficiency. With Virginia's varying climate conditions, tighter envelopes provide significant energy savings, comfort, and health benefits for occupants during all seasons. We recommend that Virginia adopt the air tightness testing requirement as published in the 2021 *IECC*.

- **Wall Insulation R-value and U-factor (Tables R402.1.2 and R402.1.4).** Virginia has applied a weaker wall insulation requirement than the *IECC* since the 2012 update, reducing comfort and energy savings for homeowners. Insulating walls is far more cost-effective at construction than in a later retrofit, so it is important that the optimal level of insulation be installed from the beginning. Unlike some equipment and other components of the building, elements of the thermal envelope such as insulation will last many decades, providing long-term benefits for homeowners. We recommend eliminating this amendment and adopting insulation requirements consistent with the 2021 *IECC*.

Greenhouse Gas Reduction and Air Quality Benefits

According to the U.S. Energy Information Administration, residential and commercial buildings account for about 40% of greenhouse gas emissions.[4] As a result, for Virginia to make meaningful progress toward greenhouse gas reduction goals, the energy used in buildings must be addressed. By adopting the 2021 *IECC* (and by reference, *ASHRAE* Standard 90.1-2019), Virginia can move ahead and capture the important energy-saving and carbon-reducing improvements incorporated into the latest model energy codes.

In addition to its energy and cost savings analyses, U.S. DOE also studied the impact of the new model energy codes on greenhouse gas reduction and the related impacts on the economy. The reduction in carbon emissions for the two most recent model energy codes are significant and should factor into the Board's consideration of the full range of benefits of adopting the latest codes as shown in the table below.

[4] *See Frequently Asked Questions (FAQs): How Much Energy is Consumed in U.S. Buildings,* U.S. Energy Infrastructure Admin., available at https://www.eia.gov/tools/faqs/faq.php?id=86&t=1s.

Residential		Commercial	
Residential Model Code	Reduction in carbon emissions over previous model code (National average)	Commercial Model Code	Reduction in carbon emissions over previous model code (National average)
2021 *IECC*	**8.66%**[5]	***ASHRAE* Std. 90.1-2019**	**4.2%**[6]

For Virginia specifically, DOE found that if the state adopts the 2021 *IECC* (as published) for residential construction, CO2 emissions will be reduced by 28,420,000 metric tons over the first 30 years.[7] This is equivalent to eliminating the annual CO2 emissions of 6,181,000 cars. Likewise, the adoption of *ASHRAE* Standard 90.1-2019 would reduce CO2 emissions by an additional 8,400,000 metric tons over the same period, the equivalent of an additional 1,824,000 cars.[8] **And in both cases, DOE found that Virginia would experience a substantial net increase of hundreds of jobs created as a result of code improvements.**[9] Adopting the 2021 *IECC* and *ASHRAE* Standard 90.1-2019 would clearly support Virginia's greenhouse gas reduction goals while positively impacting the local economy.

Broad Support for 2021 *IECC* Improvements

Like previous versions of the *IECC*, the 2021 edition was developed with the direct input of the nation's leading architects, building code officials, builders, manufacturers, environmental groups, and sustainability experts in a consensus-based code development process. During this process, the efficiency improvements proposed for the 2021 *IECC* were endorsed by a broad range of organizations, including mayors, code officials, state energy

---

[5] *See* U.S. Dep't of Energy, *Preliminary Energy Savings Analysis: 2021 IECC for Residential Buildings*, at viii (Apr. 2021), available at https://www.energycodes.gov/sites/default/files/documents/2021_IECC_PreliminaryDetermination_TSD.pdf.

[6] *See* U.S. Dep't of Energy, *Preliminary Energy Savings Analysis: ANSI/ASHRAE/IES Standard 90.1-2019*, at vi (Apr. 2021), available at https://www.energycodes.gov/sites/default/files/documents/20210407_Standard_90.1-2019_Determination_TSD.pdf.

[7] *See* U.S. Dep't of Energy, *Cost-Effectiveness of the 2021 IECC for Residential Buildings in Virginia*, at ii (July 2021), available at https://www.energycodes.gov/sites/default/files/2021-07/VirginiaResidentialCostEffectiveness_2021_0.pdf.

[8] *See* U.S. Dep't of Energy, *Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Virginia, a*t 1 (July 2021), available at https://www.energycodes.gov/sites/default/files/2021-07/Cost-effectiveness_of_ASHRAE_Standard_90-1-2019-Virginia.pdf.

[9] *See* U.S. Dep't of Energy, *Cost-Effectiveness of the 2021 IECC for Residential Buildings in Virginia*, at ii; and U.S. Dep't of Energy, *Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Virginia, a*t 1.

officials, sustainability directors, and other governmental representatives from every region of the U.S. For example, the U.S. Conference of Mayors unanimously adopted a Resolution endorsing improvements that would achieve a 10% improvement in the 2021 *IECC*, finding that:

> "… **building energy codes, by setting minimum efficiency requirements for all newly constructed and renovated residential, multi-family, and commercial buildings, provide measurable and permanent energy savings and carbon emissions reductions over the century-long life spans of these buildings** …"[10]

The 2021 *IECC* is the result of voting by governmental members who participated directly in the International Code Council Code Development process. These members voted in record numbers to improve almost every aspect of the *IECC*, paving the way for a more efficient, more sustainable future.

The 2021 *IECC* contains reasonable and significant energy-saving and carbon-reducing improvements for the entire building, including:

- Improved building envelopes, providing year-round comfort and energy savings for occupants and reducing HVAC sizing and peak demands;
- Improved requirements for verification, certificates, and other consumer protections;
- More efficient mechanical and lighting systems and automated controls designed with occupant health and safety in mind;
- Additional flexibility for builders and design professionals to optimize their design choices without reducing efficiency;
- Improved resilience, helping to protect occupants from environmental and climate-related risks and the investment of building owners; and
- A framework for jurisdictions to customize efficiency and net-zero requirements to adapt the *IECC* to meet energy and climate goals.

Delaying the adoption of potential efficiency improvements in the energy code could also have significant long-lasting negative consequences. Buildings constructed today are expected to last 70 years or more, and the vast majority of features that affect efficiency will be chosen and set in place at construction. The failure to grasp the opportunity to build more

[10] *See* U.S. Conference of Mayors, *Meeting Mayors' Energy and Climate Goals by Putting America's Model Energy Code on a Glide Path to Net Zero Energy Buildings by 2050*, USCM Resolution 59 (July 1, 2019) (emphasis added), available at https://energyefficientcodes.org/wp-content/uploads/2019-07-1-Putting-the-*IECC*-on-a-Glide-Path-to-Net-Zero-Energy-Buildings-by-2050.pdf.

efficient buildings at the outset is a tremendous loss; any delay in adoption will result in the construction of buildings with less efficiency, a condition that will last for many years and possibly for the life of such buildings. For many families, a home is often the largest single investment, and it is critical that each new home provide comfort, resilience, and energy savings from day one and for the lifetime of the building. Likewise, the owners and occupants of commercial buildings depend on the state to regulate buildings in a way that optimizes energy and cost savings and that will be consistent with Virginia's long-term energy and climate goals. The 2021 *IECC* provides a consensus-driven, adaptable blueprint for Virginia's future.

Conclusion

RECA's members and supporters have been involved in energy code development and adoption for decades, and we offer our assistance and experience as you work to maximize energy efficiency in residential and commercial buildings. Please contact us if you have any questions or would like to discuss how RECA can be of assistance.

Sincerely,

Eric Lacey
RECA Chairman

RECA is a broad coalition of energy efficiency professionals, regional efficiency organizations, product and equipment manufacturers, trade associations, and environmental organizations with expertise in the development, adoption, and implementation of building energy codes nationwide. RECA is dedicated to improving the energy efficiency of homes throughout the U.S. through greater use of energy efficient practices and building products. It is administered by the Alliance to Save Energy, a non-profit coalition of business, government, environmental and consumer leaders that supports energy efficiency as a cost-effective energy resource under existing market conditions and advocates energy-efficiency policies that minimize costs to society and individual consumers. Below is a list of RECA Members that endorse these comments.

Air Barrier Association of America

Alliance to Save Energy

American Chemistry Council

American Council for an Energy-Efficient Economy

CertainTeed LLC

EPS Industry Alliance

Extruded Polystyrene Foam Association

Institute for Market Transformation

Johns Manville Corporation

Knauf Insulation

National Fenestration Rating Council

Natural Resources Defense Council

North American Insulation Manufacturers Association

Owens Corning

Polyisocyanurate Insulation Manufacturers Association

PNNL-31535

Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Virginia

July 2021

M Tyler
Y Xie
E Poehlman
M Rosenberg

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
email: orders@ntis.gov <https://www.ntis.gov/about>
Online ordering: http://www.ntis.gov

PNNL-31535

Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Virginia

July 2021

M Tyler
Y Xie
E Poehlman
M Rosenberg

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99354

Acronyms and Abbreviations

AVERT	U.S. EPA AVoided Emissions and geneRation Tool
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BECP	Building Energy Codes Program
CH_4	Methane
CO_2	Carbon Dioxide
DOE	U.S. Department of Energy
E.O.	Executive Order
eGRID	EPA Emissions & Generation Resource Integrated Database
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FEMP	Federal Energy Management Program
HVAC	Heating, Ventilating, and Air-Conditioning
LCC	Life-Cycle Cost
MMT	Million Metric Tons
N_2O	Nitrous Oxide
NOx	Nitrogen Oxides
NIST	National Institute of Standards and Technology
PNNL	Pacific Northwest National Laboratory
SOx	Sulfur Oxides
UPV	Uniform Present Value

1.0 Highlights

Moving to the ASHRAE Standard 90.1-2019 (ASHRAE 2019) edition from Standard 90.1-2016 (ASHRAE 2016) is cost-effective for Virginia. Standard 90.1-2019 will provide an annual energy cost savings of $0.037 per square foot on average across the state. It will reduce statewide CO_2 emissions by 8.4 MMT (30 years cumulative), equivalent to the CO_2 emissions of 1,824,000 cars driven for one year.

Updating the state energy code based on Standard 90.1-2019 will also stimulate the creation of high-quality jobs across the state. Standard 90.1-2019 is expected to result in buildings that are energy efficient, more affordable to own and operate, and based on current industry standards for health, comfort, and resilience.

The tables below show the expected impact of upgrading to Standard 90.1-2019 from a consumer perspective and statewide perspective. These results are weighted averages for all building types in all climate zones in the state, based on weightings shown in Table 4. The methodology used for this analysis is consistent with the methodology used in the national cost-effectiveness analysis.[1] Additional results and details on the methodology are presented in the following sections.

Consumer Impact	
Annual (first year) energy cost savings, $/ft^2	$0.037
Added construction cost, $/ft^2	-$1.007
Publicly-owned scenario LCC Savings, $/ft^2	3.18
Privately-owned scenario LCC Savings, $/ft^2	2.76

Statewide Impact - Emissions	First Year	30 Years Cumulative
Energy cost savings, 2020$	1,140,000	508,600,000
CO_2 emission reduction, Metric tons	11,940	8,388,000
CH_4 emissions reductions, Metric tons	0.63	445
N_2O emissions reductions, Metric tons	0.085	59
NOx emissions reductions, Metric tons	6.26	4,396
SOx emissions reductions, Metric tons	8.21	5,768

Statewide Impact - Jobs Created	First Year	30 Years Cumulative
Jobs Created Reduction in Utility Bills	92	2,947
Jobs Created Construction Related Activities	214	6,807

[1] National cost-effectiveness report: https://www.energycodes.gov/development/commercial/cost_effectiveness

The report provides analysis of two LCC scenarios:

- **Scenario 1**, representing *publicly-owned* buildings, considers initial costs, energy costs, maintenance costs, and replacement costs—without borrowing or taxes.
- **Scenario 2**, representing *privately-owned* buildings, adds borrowing costs and tax impacts.

Figure 1 compares annual energy cost savings, first cost for the upgrade, and net annualized LCC savings. The net annualized LCC savings per square foot is the annual energy savings minus an allowance to pay for the added cost under scenario 1. Figure 2 shows overall state weighted net LCC results for both scenarios. When net LCC is positive, the updated code edition is considered cost-effective.

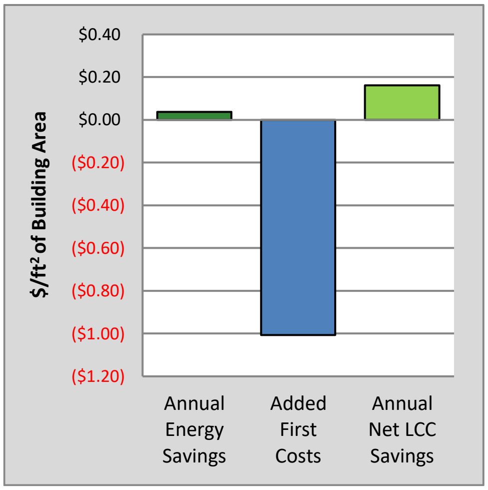

Figure 1. Statewide Weighted Costs and Savings

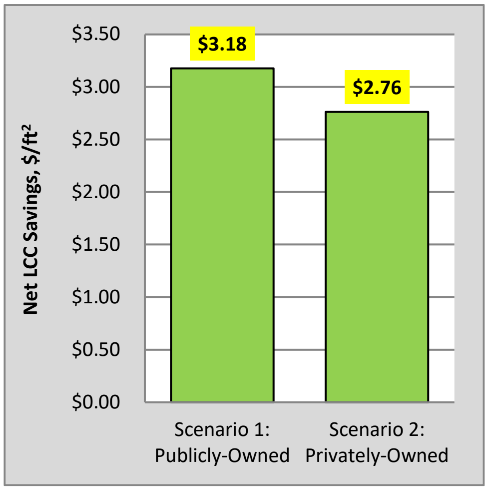

Figure 2. Overall Net Life-Cycle Cost Savings

2.0 Cost-Effectiveness Results for ASHRAE Standard 90.1-2019 in Virginia

This section summarizes the cost-effectiveness analysis results applicable to the building owner. Life Cycle Cost (LCC) savings is the primary measure established by the U.S. Department of Energy to assess the cost effectiveness and economic impact of building energy codes. Net LCC savings is the calculation of the present value of energy savings minus the present value of non-energy incremental costs over a 30-year period. The non-energy incremental costs include initial equipment and construction costs, and maintenance and replacement costs, less the residual value of components at the end of the 30-year period. When net LCC is positive, the updated code edition is considered cost-effective. Savings are computed for two scenarios:

- **Scenario 1:** represents *publicly-owned buildings*, includes costs for initial equipment and construction, energy, maintenance and replacement and does not include loans or taxes.
- **Scenario 2:** represents *privately-owned buildings*, includes the same costs as Scenario 1, with the initial investment financed through a loan amortized over 30 years and federal and state corporate income tax deductions for interest and depreciation.

Both scenarios include the residual value of equipment with remaining useful life at the end of the 30-year assessment period. Totals for building types, climate zones, and the state overall are averages based on Table 4 construction weights. Factors such as inflation and discount rates are different between the two scenarios, as described in the Cost-Effectiveness Methodology section.

LCC is affected by many variables, including the applicability of individual measures in the code, measure costs, measure lifetime, replacement costs, state cost adjustment, energy prices, and so on. In some cases, the LCC can be negative for a given building type or climate zone based on the interaction of these variables. However, the code is considered cost-effective if the weighted statewide LCC is positive.

Table 1 shows the present value of the net LCC savings over 30 years for buildings in scenario 1 averages $3.18 per square foot for Standard 90.1-2019.

Table 1. Net LCC Savings for Virginia, Scenario 1 ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$3.55	$3.63	$3.65	$4.14	$12.16	$2.48	$3.52
4A	$3.52	$3.60	$3.68	$4.15	$12.14	$1.74	$3.10
5A	$3.36	$3.41	$3.63	$4.20	$12.07	$1.79	$8.29
State Average	$3.53	$3.60	$3.67	$4.15	$12.14	$1.86	**$3.18**

Table 2 shows the present value of the net LCC savings over 30 years averages $2.76 per square foot for scenario 2.

Table 2. Net LCC Savings for Virginia, Scenario 2 ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$2.97	$2.98	$3.14	$3.50	$11.76	$2.24	$3.09
4A	$2.94	$2.94	$3.17	$3.47	$11.73	$1.57	$2.69
5A	$2.80	$2.78	$3.11	$3.52	$11.67	$1.62	$7.80
State Average	$2.95	$2.94	$3.16	$3.48	$11.74	$1.68	**$2.76**

2.1 Energy Cost Savings

Table 3 shows the economic impact of upgrading to Standard 90.1-2019 by building type and climate zone in terms of the annual energy cost savings in dollars per square foot. The annual energy cost savings across the state averages $0.037 per square foot.

Table 3. Annual Energy Cost Savings for Virginia ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	$0.034	$0.048	$0.064	$0.057	$0.061	$0.047	$0.051
4A	$0.032	$0.042	$0.063	$0.046	$0.060	$0.013	$0.034
5A	$0.031	$0.037	$0.059	$0.047	$0.056	$0.013	$0.053
State Average	$0.033	$0.042	$0.063	$0.048	$0.060	$0.019	**$0.037**

2.2 Construction Weighting of Results

Energy and economic impacts were determined and reported separately for each building type and climate zone. Cost-effectiveness results are also reported as averages for all prototypes and climate zones in the state. To determine these averages, results were combined across the different building types and climate zones using weighting factors shown in Table 4. These weighting factors are based on the floor area of new construction and major renovations for the six analyzed building prototypes in state-specific climate zones. The weighting factors were developed from construction start data from 2003 to 2018 (Dodge Data & Analytics) based on an approach documented in Lei, et al.

Table 4. Construction Weights by Building Type

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	2.5%	1.2%	4.4%	1.8%	0.6%	7.0%	17.6%
4A	6.7%	14.6%	16.4%	7.6%	2.2%	34.8%	82.3%
5A	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
State Average	9.2%	15.8%	20.9%	9.4%	2.8%	41.8%	100.0%

2.3 Incremental Construction Cost

Cost estimates were developed for the differences between Standard 90.1-2016 and Standard 90.1-2019 as implemented in the six prototype models. Costs for the initial construction include material, labor, commissioning, construction equipment, overhead and profit. Costs were also estimated for replacing equipment or components at the end of the useful life. The costs were developed at the national level for the national cost-effectiveness analysis and then adjusted for local conditions using a state construction cost index (Hart et al. 2019, Means 2020a,b).

Table 5 shows incremental initial cost for individual building types in state-specific climate zones and weighted average costs by climate zone and building type for moving to Standard 90.1-2019 from Standard 90.1-2016.

The added construction cost can be negative for some building types, which represents a reduction in first costs and a savings that is included in the net LCC savings. This is typically due to the interaction between measures and situations such as the following:

- Fewer light fixtures are required when the allowed lighting power is reduced. Also, changes from fluorescent to LED technology result in reduced lighting costs in many cases and longer lamp lives, requiring fewer lamp replacements.
- Smaller heating, ventilating, and air-conditioning (HVAC) equipment sizes can result from the lowering of heating and cooling loads due to other efficiency measures, such as better building envelopes. For example, Standard 90.1-2019 has more stringent fenestration U-factors for some climate zones. This results in smaller equipment and distribution systems, resulting in a negative first cost.

Table 5. Incremental Construction Cost for Virginia ($/ft^2)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	($1.648)	($1.844)	($1.203)	($1.696)	$0.611	($0.317)	($0.942)
4A	($1.642)	($1.926)	($1.230)	($1.872)	$0.601	($0.338)	($1.021)
5A	($1.574)	($1.849)	($1.252)	($1.885)	$0.605	($0.368)	($0.396)
State Average	($1.644)	($1.919)	($1.225)	($1.838)	$0.603	($0.335)	**($1.007)**

2.4 Simple Payback

Simple payback is the total incremental first cost divided by the annual savings, where the annual savings is the annual energy cost savings less any incremental annual maintenance cost. Simple payback is not used as a measure of cost-effectiveness as it does not account for the time value of money, the value of energy cost savings that occur after payback is achieved, or any replacement costs that occur after the initial investment. However, it is included in the analysis for states who wish to use this information. Table 6 shows simple payback results in years.

Table 6. Simple Payback for Virginia (Years)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
3A	Immediate	Immediate	Immediate	Immediate	10.0	Immediate	Immediate
4A	Immediate	Immediate	Immediate	Immediate	10.1	Immediate	Immediate
5A	Immediate	Immediate	Immediate	Immediate	10.8	Immediate	Immediate
State Average	Immediate	Immediate	Immediate	Immediate	10.0	Immediate	**Immediate**

3.0 Societal Benefits

3.1 Benefits of Energy Codes

It is estimated that by 2060, the world will add 2.5 trillion square feet of buildings, an area equal to the current building stock. As a building's operation and environmental impact is largely determined by upfront decisions, energy codes present a unique opportunity to assure savings through efficient building design, technologies, and construction practices. Once a building is constructed, it is significantly more expensive to achieve higher efficiency levels through later modifications and retrofits. Energy codes ensure that a building's energy use is included as a fundamental part of the design and construction process. Making this early investment in energy efficiency will pay dividends to residents of Virginia for years into the future.

3.2 Greenhouse Gas Emissions

The urban built environment is responsible for 75% of annual global greenhouse gas (GHG) emissions while buildings alone account for 39%.[2] While carbon dioxide emissions represent the largest share of greenhouse gas emissions, building electricity use and on-site fossil fuel consumption also contribute to other emissions, two of which, methane (CH_4) and nitrous oxide (N_2O), are significant greenhouse gases in their own right.

For natural gas combusted on site, emission metrics are developed using nationwide emission factors from U.S. Environmental Protection Agency publications for CO_2, NOx, SO_2, CH_4 and N_2O (EPA 2014).

For electricity, marginal carbon emission factors are provided by the U.S. Environmental Protection Agency (EPA) AVoided Emissions and geneRation Tool (AVERT) version 3.0 (EPA 2020). The AVERT tool forms the basis of the national marginal emission factors for electricity also published by EPA on its Greenhouse Gas Equivalencies Calculator website and are based on a portfolio of energy efficiency measures examined by EPA. AVERT is used here to provide marginal CO_2 emission factors at the State level.[3] AVERT also provides marginal emission factor estimates for gaseous pollutants associated with electricity production, including NOx and SO_2 emissions. While not considered significant greenhouse gases, these are EPA tracked pollutants. The current analysis uses AVERT to provide estimates of corresponding emission changes for NOx and SO_2 in physical units but does not monetize these.

AVERT does not develop associated marginal emissions factors for CH_4 or N_2O. To provide estimates for the associated emission reductions for CH_4 and N_2O, this report uses emission factors separately provided through the U.S. Environmental Protection Agency (EPA) Emissions

[2] Architecture 2030, https://architecture2030.org/2030_challenges/2030-challenge

[3] AVERT models avoided emissions in 14 geographic regions of the 48 contiguous United States and includes transmission and distribution losses. Where multiple AVERT regions overlap a state's boundaries, the emission factors are calculated based on apportionment of state electricity savings by generation across generation regions. The most recent AVERT 3.0 model uses EPA emissions data for generators from 2019. Note that AVERT estimates are based on marginal changes to demand and reflect current grid generation mix. Emission factors for electricity shown in Table 7 do not take into account long term policy or technological changes in the regional generation mix that can impact the marginal emission benefits from new building codes.

& Generation Resource Integrated Database (eGRID) dataset. eGRID is a comprehensive source of data on the environmental characteristics of almost all electric power generated in the United States and the emission characteristics for electric power generation for each of the above emissions can also be found aggregated down to the state level in eGRID (EPA 2021a). The summary emission factor data provided by eGRID does not provide marginal emission factors, but instead summarizes emission factors in terms of total generation emission factors and non-baseload generation emission factors. Non-baseload emission factors established in eGRID are developed based on the annual load factors for the individual generators tracked by the EPA (EPA 2021b). Because changes in building codes are unlikely to significantly impact baseload electrical generators, the current analysis uses the 2019 non-baseload emission factors established in eGRID by state to estimate CH_4 or N_2O emission reductions due to changes in electric consumption.

Table 7 summarizes the marginal emission factors available from AVERT, eGRID and the EPA Greenhouse Gas Equivalencies Calculator.

Table 7. Greenhouse Gas Emission Factors by Fuel Type

GHG	Electricity lb/MWh	Natural Gas (lb/mmcf)
CO_2	1,567	120,000
SO_2	1.194	0.6
NO_X	0.774	96
N_2O	0.012	0.23
CH_4	0.089	2.3

Table 8 shows the annual first year and projected 30-year energy cost savings. This table also shows first year and projected 30-year greenhouse gas (CO_2, CH_4, and N_2O) emission reductions, in addition to NOx and SO_2 reductions.

Table 8. Societal Benefits of Standard 90.1-2019

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, 2020$	1,140,000	508,600,000
CO_2 emission reduction, Metric tons	11,940	8,388,000
CH_4 emissions reductions, Metric tons	0.63	445
N_2O emissions reductions, Metric tons	0.085	59
NOx emissions reductions, Metric tons	6.26	4,396
SOx emissions reductions, Metric tons	8.21	5,768

3.3 Jobs Creation through Energy Efficiency

Energy-efficient building codes impact job creation through two primary value streams:

1. Dollars returned to the economy through reduction in utility bills and resulting increase in disposable income, and;
2. An increase in construction-related activities associated with the incremental cost of construction that is required to produce a more energy efficient building.

When a building is built to a more stringent energy code, there is the long-term benefit of the ratepayer paying lower utility bills.

- This is partially offset by the increased cost of that efficiency, establishing a relationship between increased building energy efficiency and additional investments in construction activity.

- Since building codes are cost-effective, (i.e., the savings outweigh the investment), a real and permanent increase in wealth occurs that can be spent on other goods and services in the economy, just like any other income, generating economic benefits and creating additional employment opportunities.

Table 9 shows the number of jobs created because of efficiency gains in Standard 90.1-2019.

Table 9. Jobs Created from Standard 90.1-2019

Statewide Impact	First Year	30 Years Cumulative
Jobs Created Reduction in Utility Bills	92	2,947
Jobs Created Construction Related Activities	214	6,807

4.0 Overview of the Cost-Effectiveness Methodology

This analysis was conducted by Pacific Northwest National Laboratory (PNNL) in support of the DOE Building Energy Codes Program. DOE is directed by federal law to provide technical assistance supporting the development and implementation of residential and commercial building energy codes. The national model energy codes – the International Energy Conservation Code (IECC) and ANSI/ASHRAE/IES Standard 90.1 – help adopting states and localities establish minimum requirements for energy-efficient building design and construction, as well as mitigate environmental impacts and ensure residential and commercial buildings are constructed to modern industry standards.

The current analysis evaluates the cost-effectiveness of Standard 90.1-2019 relative to Standard 90.1-2016. The analysis covers six commercial building types. The analysis is based on the current prescriptive requirements of Standard 90.1. The simulated performance rating method is not in the scope of this analysis, as it is generally based on the core prescriptive requirements of Standard 90.1, and due to the unlimited range of building configurations that are allowed. Buildings complying via this path are generally considered to provide equal or better energy performance compared to the prescriptive requirements, as the intent of these paths is to provide additional design flexibility and cost optimization, as dictated by the builder, designer, and owner.

The current analysis is based on the methodology by DOE for assessing building energy codes (Hart and Liu 2015). The LCC analysis perspective described in the methodology appropriately balances upfront costs with longer term consumer costs and savings and is therefore the primary economic metric by which DOE evaluates the cost-effectiveness of building energy codes.

4.1 Cost-Effectiveness

DOE has established standard economic LCC cost-effectiveness analysis methods in comparing Standard 90.1-2019 and Standard 90.1-2016, which are described in *Methodology for Evaluating Cost-effectiveness of Commercial Energy Code Changes* (Hart and Liu 2015). Under this methodology, two metrics are used:

- **Net LCC Savings:** This is the calculation of the present value of energy savings minus the present value of non-energy incremental costs over a 30-year period. The costs include initial equipment and construction costs, maintenance and replacement costs, less the residual value of components at the end of the 30-year period. When net LCC is positive, the updated code edition is considered cost-effective.
- **Simple Payback:** While not a true cost-effectiveness metric, simple payback is also calculated. Simple payback is the number of years required for accumulated annual energy cost savings to exceed the incremental first costs of a new code.

Two cost scenarios are analyzed:

- **Scenario 1** represents publicly-owned buildings, considers initial costs, energy costs, maintenance costs, and replacement costs without borrowing or taxes.
- **Scenario 2** represents privately-owned buildings and includes the same costs as Scenario 1 plus financing of the incremental first costs through increased borrowing with tax impacts including mortgage interest and depreciation deductions. Corporate tax rates are applied.

The cost-effectiveness analysis compares the cost for new buildings meeting Standard 90.1-2019 versus new buildings meeting Standard 90.1-2016. The analysis includes energy savings estimates from building energy simulations and LCC and simple payback calculations using standard economic analysis parameters. The analysis builds on work documented in *Energy Savings Analysis: ANSI/ASHRAE/IES Standard 90.1-2019* (DOE 2021), and the national cost-effectiveness analysis documented in *National Cost-effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019* (Tyler et al. 2021).

4.2 Building Prototypes and Energy Modeling

The cost-effectiveness analysis uses six building types represented by six prototype building energy models. These six models represent the energy impact of five of the eight commercial principal building activities that account for 74% of the new construction by floor area covered by the full suite of 16 prototypes. These models provide coverage of the significant changes in ASHRAE Standard 90.1 from 2016 to 2019 and are used to show the impacts of the changes on annual energy usage. The prototypes represent common construction practice and include the primary conventional HVAC systems most commonly used in commercial buildings.[4]

Each prototype building is analyzed for each of the climate zones found within the state. Using the U.S. DOE EnergyPlus software, the six building prototypes summarized in Table 10 are simulated with characteristics meeting the requirements of Standard 90.1-2016 and then modified to meet the requirements of the next edition of the code (Standard 90.1-2019). The energy use and energy cost are then compared between the two sets of models.

Table 10. Building Prototypes

Building Prototype	Floor Area (ft²)	Number of Floors
Small Office	5,500	1
Large Office	498,640	13
Stand-Alone Retail	24,690	1
Primary School	73,970	1
Small Hotel	43,210	4
Mid-Rise Apartment	33,740	4

4.3 Climate Zones

Climate zones are defined in ASHRAE Standard 169, as specified in ASHRAE Standard 90.1, and include eight primary climate zones in the United States, the hottest being climate zone 1 and the coldest being climate zone 8. Letters A, B, and C are applied in some cases to denote the level of moisture, with A indicating humid, B indicating dry, and C indicating marine. Figure 3 shows the national climate zones. For this state analysis, savings are analyzed for each climate zone in the state using weather data from a selected city within the climate zone and state, or where necessary, a city in an adjoining state with more robust weather data.

[4] More information on the prototype buildings and savings analysis can be found at www.energycodes.gov/development/commercial/90.1_models

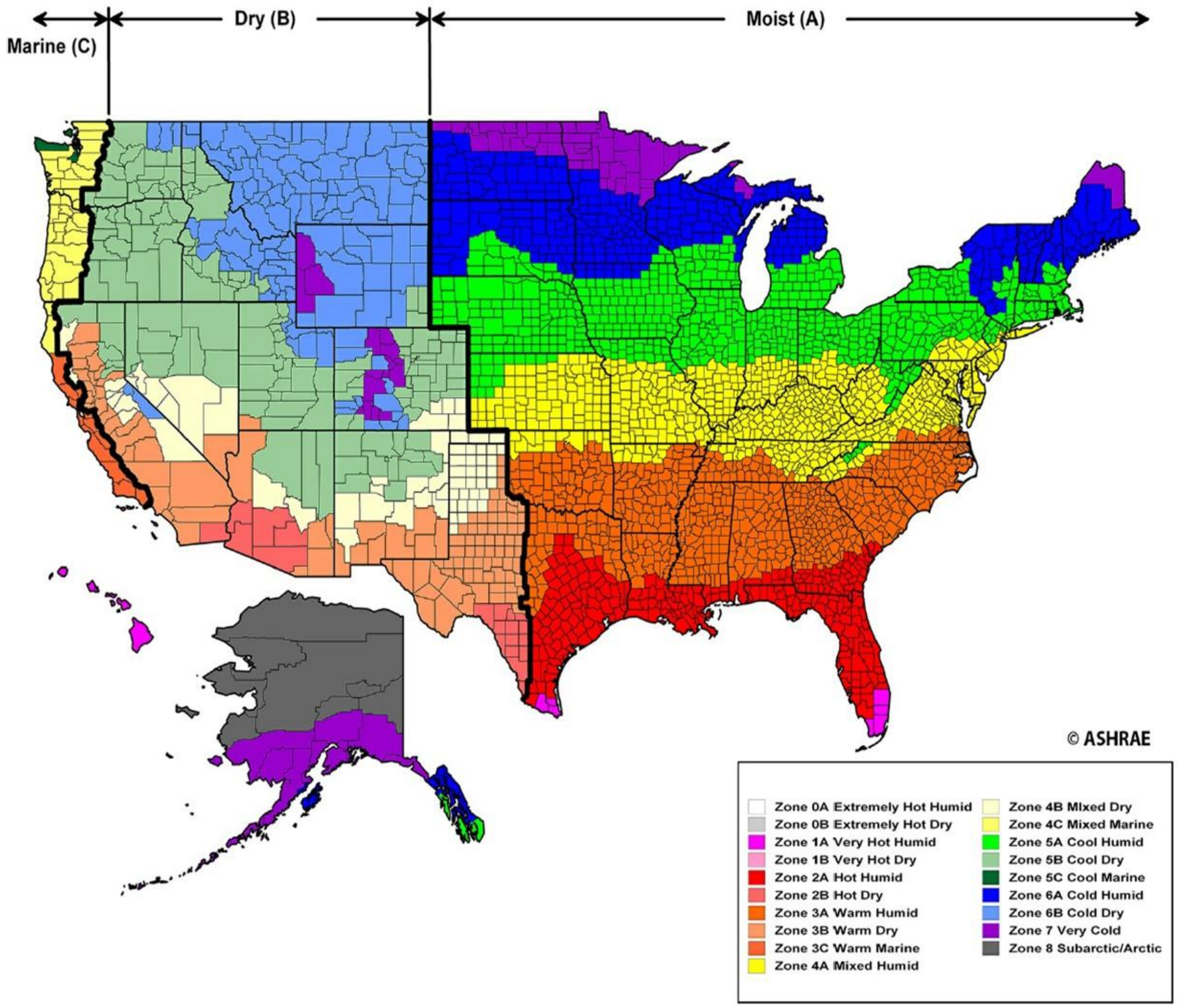

Figure 3. National Climate Zones

4.4 Cost-Effectiveness Method and Parameters

The DOE cost-effectiveness methodology accounts for the benefits of energy efficient building construction over a multi-year analysis period, balancing initial costs against longer term energy savings. DOE evaluates energy codes and code proposals based on LCC analysis over a multi-year study period, accounting for energy savings, incremental investment for energy efficiency measures, and other economic impacts. The value of future savings and costs are discounted to a present value, with improvements deemed cost-effective when the net LCC savings (present value of savings minus cost) is positive.

The U.S. DOE Building Energy Codes Program has established LCC analysis criteria similar to the method used for many federal building projects, as well as other public and private building projects (Fuller and Petersen 1995). The LCC analysis method consists of identifying costs (and revenues if any) and in what year they occur; then determining their value in today's dollars (known as the present value). This method uses economic relationships about the time value of money. Money in-hand today is normally worth more than money received in the future, which is why we pay interest on a loan and earn interest on savings. Future costs are discounted to the present based on a discount rate. The discount rate may reflect the interest rate at which money can be borrowed for projects with the same level of risk or the interest rate that can be earned on other conventional investments with similar risk.

The LCC includes incremental initial costs, repairs, maintenance, and replacements. Scenario 2 also includes loan costs and tax impacts including mortgage interest and depreciation deductions. The residual value of equipment (or other component such as roof membrane) that has remaining useful life at the end of the 30-year study period is also included for both scenarios. The residual value is calculated by multiplying the initial cost of the component by the years of useful life remaining for the component at year 30 divided by the total useful life, a simplified approach included in the Federal Energy Management Program (FEMP) LCC method (Fuller and Petersen 1995). A component will have zero residual value at year 30 only if it has a 30-year life, or if it has a shorter than 30-year life that divides exactly into 30 years (for example, a 15-year life).

The financial and economic parameters used for the LCC calculations are shown in Table 11.

Table 11. LCC Economic Parameters

Economic Parameter	Scenario 1	Scenario 2
Study Period – Years[1]	30	30
Nominal Discount Rate[2]	3.10%	5.25%
Real Discount Rate[2]	3.00%	3.34%
Effective Inflation Rate[3]	0.10%	1.85%
Electricity Prices[4] (per kWh)	$0.0770	$0.0770
Natural Gas Prices[4] (per therm)	$0.8438	$0.8438
Energy Price Escalation Factors[5]	*Uniform present value factors*	*Uniform present value factors*
Electricity Price UPV[5]	19.17	17.37
Natural Gas Price UPV[5]	23.45	21.25
Loan Interest Rate[6]	NA	5.25%
Federal Corporate Tax Rate[7]	NA	21.00%
State Corporate Tax Rate[8]	NA	6.00%
Combined Income Tax Impact[9]	NA	25.74%
State and Average Local Sales Tax[10]	5.65%	5.65%
State Construction Cost Index[11]	0.887	0.887

[1] A 30-year study period captures most building components useful lives and is a commonly used study period for building project economic analysis. This period is consistent with previous and related national 90.1 cost-effectiveness analysis. It is also consistent with the cost-effectiveness analysis that was done for the residential energy code as described in multiple state reports and a summary report (Mendon et al. 2015). The federal building LCC method uses 25 years and the ASHRAE Standard 90.1 development process uses up to 40 years for building envelope code improvement analysis. Because of the time value of money, results are typically similar for any study periods of 20 years or more.

[2] The Scenario 1 real and nominal discount rates are from the National Institute of Standards and Technology (NIST) 2019 annual update in the *Report of the President's Economic Advisors, Analytical Perspectives* (referenced in the NIST 2019 annual supplement without citation) (Lavappa and Kneifel 2019). The Scenario 2 nominal discount rate is taken as the marginal cost of capital, which is set equal to the loan interest rate (see footnote 6). The real discount rate for Scenario 2 is calculated from the nominal discount rate and inflation.

[3] The Scenario 1 effective inflation rate is from the NIST 2019 annual update for the federal LCC method (Lavappa and Kneifel 2019). The Scenario 2 inflation rate is the 30-year average Producer Price Index for non-residential construction, June 1990 to June 2020 (Bureau of Labor Statistics 2021).

[4] Scenario 1 and 2 electricity and natural gas prices are state average annual prices for 2020 from the United States Energy Information Administration (EIA) *Electric Power Monthly* (EIA 2021a) and *Natural Gas Monthly* (EIA 2021b).

[5] Scenario 1 energy price escalation rates are from the NIST 2019 annual update for the FEMP LCC method (Lavappa and Kneifel 2019). The NIST uniform present value (UPV) factors are multiplied by the first-year annual energy cost to determine the present value of 30 years of energy costs and are based on a series of different annual escalation rates for 30 years. Scenario 2 UPV factors are based on NIST UPVs with an adjustment made for the scenario difference in discount rates.

[6] The loan interest rate is estimated from multiple online sources listed in the references (Commercial Loan Direct 2021; Realty Rates 2021).

[7] The highest federal marginal corporate income tax rate is applied.

[8] The highest marginal state corporate income tax rate is applied from the Federation of Tax Administrators (FTA 2021).

[9] The combined tax impact is based on state tax being a deduction for federal tax and is applied to depreciation and loan interest.

[10] The combined state and average local sales tax is included in material costs in the cost estimate (Tax Foundation 2020).

[11] The state construction cost index is based on weighted city indices from the state (Means 2020b).

5.0 Detailed Energy Use and Cost

On the following pages, specific detailed results for Virginia are included:

- Table 12 shows the average energy rates used.
- Table 13 shows the per square foot energy costs for Standard 90.1-2016 and Standard 90.1-2019 and the cost savings from Standard 90.1-2019.
- Table 14 shows the per square foot energy use for Standard 90.1-2016 and Standard 90.1-2019 and the energy use savings from Standard 90.1-2019.
- Tables 15.A through 15.C show the energy end use by energy type for each climate zone in the state.

Table 12. Energy Rates for Virginia, Average $ per unit

Electricity	$0.0770	kWh
Gas	$0.8438	Therm

Source: Energy Information Administration, annual average prices for 2020 (EIA 2021a,b)

Table 13. Energy Cost Saving Results in Virginia, $ per Square Foot

Climate Zone:	3A				4A				5A			
Code:	90.1-2016	90.1-2019	Savings		90.1-2016	90.1-2019	Savings		90.1-2016	90.1-2019	Savings	
Small Office												
Electricity	$0.584	$0.550	$0.034	5.8%	$0.576	$0.544	$0.033	5.7%	$0.556	$0.525	$0.032	5.8%
Gas	$0.003	$0.003	$0.000	0.0%	$0.002	$0.002	$0.000	0.0%	$0.013	$0.014	-$0.001	-7.7%
Totals	$0.586	$0.553	$0.034	5.8%	$0.578	$0.545	$0.032	5.5%	$0.570	$0.539	$0.031	5.4%
Large Office												
Electricity	$1.186	$1.144	$0.042	3.5%	$1.190	$1.148	$0.041	3.4%	$1.148	$1.111	$0.037	3.2%
Gas	$0.024	$0.017	$0.007	29.2%	$0.016	$0.016	$0.001	6.3%	$0.023	$0.023	$0.001	4.3%
Totals	$1.210	$1.162	$0.048	4.0%	$1.206	$1.164	$0.042	3.5%	$1.171	$1.134	$0.037	3.2%
Stand-Alone Retail												
Electricity	$0.752	$0.681	$0.071	9.4%	$0.756	$0.686	$0.070	9.3%	$0.683	$0.614	$0.069	10.1%
Gas	$0.106	$0.113	-$0.007	-6.6%	$0.099	$0.106	-$0.007	-7.1%	$0.161	$0.171	-$0.010	-6.2%
Totals	$0.858	$0.794	$0.064	7.5%	$0.855	$0.792	$0.063	7.4%	$0.844	$0.785	$0.059	7.0%
Primary School												
Electricity	$0.744	$0.692	$0.052	7.0%	$0.744	$0.699	$0.045	6.0%	$0.671	$0.626	$0.045	6.7%
Gas	$0.093	$0.087	$0.005	5.4%	$0.073	$0.072	$0.001	1.4%	$0.099	$0.096	$0.002	2.0%
Totals	$0.837	$0.779	$0.057	6.8%	$0.817	$0.771	$0.046	5.6%	$0.770	$0.723	$0.047	6.1%
Small Hotel												
Electricity	$0.708	$0.647	$0.061	8.6%	$0.706	$0.647	$0.060	8.5%	$0.678	$0.622	$0.056	8.3%
Gas	$0.188	$0.188	$0.000	0.0%	$0.191	$0.191	$0.000	0.0%	$0.209	$0.209	$0.000	0.0%
Totals	$0.897	$0.835	$0.061	6.8%	$0.897	$0.838	$0.060	6.7%	$0.887	$0.831	$0.056	6.3%
Mid-Rise Apartment												
Electricity	$0.775	$0.755	$0.019	2.5%	$0.783	$0.768	$0.015	1.9%	$0.769	$0.753	$0.016	2.1%
Gas	$0.042	$0.015	$0.028	66.7%	$0.010	$0.011	-$0.002	-20.0%	$0.021	$0.024	-$0.003	-14.3%
Totals	$0.817	$0.770	$0.047	5.8%	$0.792	$0.779	$0.013	1.6%	$0.790	$0.776	$0.013	1.6%

Table 14. Energy Use Saving Results in Virginia, Energy Use per Square Foot

Climate Zone:	3A				4A				5A			
Code:	90.1-2016	90.1-2019	Savings		90.1-2016	90.1-2019	Savings		90.1-2016	90.1-2019	Savings	
Small Office												
Electricity, kWh/ft^2	7.579	7.141	0.437	5.8%	7.481	7.059	0.423	5.7%	7.227	6.817	0.411	5.7%
Gas, therm/ft^2	0.003	0.003	0.000	0.0%	0.002	0.002	0.000	0.0%	0.016	0.017	-0.001	-6.3%
Totals, kBtu/ft^2	26.166	24.692	1.474	5.6%	25.725	24.299	1.425	5.5%	26.258	24.924	1.334	5.1%
Large Office												
Electricity, kWh/ft^2	15.401	14.861	0.540	3.5%	15.453	14.916	0.538	3.5%	14.909	14.432	0.477	3.2%
Gas, therm/ft^2	0.028	0.021	0.008	28.6%	0.019	0.019	0.001	5.3%	0.028	0.027	0.001	3.6%
Totals, kBtu/ft^2	55.391	52.777	2.614	4.7%	54.683	52.769	1.915	3.5%	53.648	51.956	1.692	3.2%
Stand-Alone Retail												
Electricity, kWh/ft^2	9.772	8.848	0.924	9.5%	9.817	8.910	0.908	9.2%	8.864	7.973	0.891	10.1%
Gas, therm/ft^2	0.125	0.133	-0.008	-6.4%	0.118	0.125	-0.008	-6.8%	0.191	0.202	-0.012	-6.3%
Totals, kBtu/ft^2	45.859	43.535	2.323	5.1%	45.257	42.936	2.321	5.1%	49.333	47.458	1.875	3.8%
Primary School												
Electricity, kWh/ft^2	9.667	8.989	0.678	7.0%	9.658	9.077	0.580	6.0%	8.718	8.134	0.584	6.7%
Gas, therm/ft^2	0.110	0.103	0.006	5.5%	0.086	0.085	0.001	1.2%	0.117	0.114	0.003	2.6%
Totals, kBtu/ft^2	43.963	41.026	2.937	6.7%	41.608	39.479	2.129	5.1%	41.430	39.166	2.264	5.5%
Small Hotel												
Electricity, kWh/ft^2	9.201	8.404	0.797	8.7%	9.174	8.398	0.777	8.5%	8.808	8.078	0.730	8.3%
Gas, therm/ft^2	0.223	0.223	0.000	0.0%	0.226	0.227	0.000	0.0%	0.248	0.248	0.000	0.0%
Totals, kBtu/ft^2	53.703	51.004	2.699	5.0%	53.949	51.327	2.622	4.9%	54.846	52.355	2.492	4.5%
Mid-Rise Apartment												
Electricity, kWh/ft^2	10.061	9.810	0.251	2.5%	10.168	9.975	0.193	1.9%	9.987	9.775	0.213	2.1%
Gas, therm/ft^2	0.050	0.018	0.033	66.0%	0.011	0.013	-0.002	-18.2%	0.024	0.028	-0.004	-16.7%
Totals, kBtu/ft^2	39.351	35.234	4.117	10.5%	35.832	35.391	0.441	1.2%	36.521	36.182	0.339	0.9%

Table 15.A. Annual Energy Usage for Buildings in Virginia in Climate Zone 3A

Energy End-Use	Small Office		Large Office		Stand-Alone Retail		Primary School		Small Hotel		Mid-Rise Apartment	
	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr
ASHRAE 90.1-2016												
Heating, Humidification	0.383	0.003	0.532	0.018	0.000	0.090	0.000	0.049	0.343	0.008	0.000	0.050
Cooling	1.032	0.000	2.265	0.000	2.249	0.000	1.981	0.000	2.067	0.000	1.080	0.000
Fans, Pumps, Heat Recovery	0.890	0.000	1.373	0.000	1.522	0.000	1.522	0.000	1.062	0.000	0.660	0.000
Lighting, Interior & Exterior	1.926	0.000	1.962	0.000	3.815	0.000	1.464	0.000	2.142	0.000	1.055	0.000
Plugs, Refrigeration, Other	2.439	0.000	9.269	0.000	2.187	0.000	4.602	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.010	0.000	0.035	0.097	0.015	0.000	0.123	3.058	0.000
Total	7.579	0.003	15.401	0.028	9.772	0.125	9.667	0.110	9.201	0.223	10.061	0.050
ASHRAE 90.1-2019												
Heating, Humidification	0.391	0.003	0.532	0.010	0.000	0.098	0.000	0.043	0.392	0.008	0.000	0.018
Cooling	0.981	0.000	2.099	0.000	2.103	0.000	1.842	0.000	1.944	0.000	1.027	0.000
Fans, Pumps, Heat Recovery	0.818	0.000	1.330	0.000	1.452	0.000	1.391	0.000	1.008	0.000	0.620	0.000
Lighting, Interior & Exterior	1.603	0.000	1.631	0.000	3.106	0.000	1.200	0.000	1.474	0.000	0.901	0.000
Plugs, Refrigeration, Other	2.438	0.000	9.269	0.000	2.186	0.000	4.459	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.010	0.000	0.035	0.097	0.015	0.000	0.123	3.054	0.000
Total	7.141	0.003	14.861	0.021	8.848	0.133	8.989	0.103	8.404	0.223	9.810	0.018
Total Savings	0.437	0.000	0.540	0.008	0.924	-0.008	0.678	0.006	0.797	0.000	0.251	0.033

Table 15.B. Annual Energy Usage for Buildings in Virginia in Climate Zone 4A

Energy End-Use	Small Office		Large Office		Stand-Alone Retail		Primary School		Small Hotel		Mid-Rise Apartment	
	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr
ASHRAE 90.1-2016												
Heating, Humidification	0.289	0.002	0.585	0.009	0.000	0.082	0.000	0.025	0.324	0.009	0.000	0.011
Cooling	1.065	0.000	2.211	0.000	2.281	0.000	2.008	0.000	2.080	0.000	1.134	0.000
Fans, Pumps, Heat Recovery	0.892	0.000	1.433	0.000	1.545	0.000	1.543	0.000	1.068	0.000	0.659	0.000
Lighting, Interior & Exterior	1.887	0.000	1.955	0.000	3.805	0.000	1.408	0.000	2.116	0.000	1.055	0.000
Plugs, Refrigeration, Other	2.439	0.000	9.269	0.000	2.186	0.000	4.602	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.010	0.000	0.036	0.097	0.015	0.000	0.125	3.112	0.000
Total	7.481		15.453	0.019	9.817	0.118	9.658	0.086	9.174	0.226	10.168	0.011
ASHRAE 90.1-2019												
Heating, Humidification	0.297		0.585	0.008	0.000	0.090	0.000	0.024	0.384	0.009	0.000	0.013
Cooling	1.014	0.000	2.060	0.000	2.146	0.000	1.923	0.000	1.953	0.000	1.108	0.000
Fans, Pumps, Heat Recovery	0.823	0.000	1.374	0.000	1.478	0.000	1.436	0.000	1.014	0.000	0.645	0.000
Lighting, Interior & Exterior	1.577	0.000	1.628	0.000	3.099	0.000	1.163	0.000	1.459	0.000	0.901	0.000
Plugs, Refrigeration, Other	2.439	0.000	9.269	0.000	2.186	0.000	4.458	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.010	0.000	0.036	0.097	0.015	0.000	0.125	3.113	0.000
Total	7.059		14.916	0.019	8.910	0.125	9.077	0.085	8.398	0.227	9.975	0.013
Total Savings	0.423	0.000	0.538	0.001	0.908	-0.008	0.580	0.001	0.777	0.000	0.193	-0.002

Table 15.C. Annual Energy Usage for Buildings in Virginia in Climate Zone 5A

Energy End-Use	Small Office		Large Office		Stand-Alone Retail		Primary School		Small Hotel		Mid-Rise Apartment	
	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr	Electric kWh/ ft²·yr	Gas therms/ ft²·yr
ASHRAE 90.1-2016												
Heating, Humidification	0.564	0.016	0.763	0.016	0.000	0.154	0.000	0.054	0.588	0.015	0.000	0.024
Cooling	0.557	0.000	1.512	0.000	1.133	0.000	1.152	0.000	1.457	0.000	0.686	0.000
Fans, Pumps, Heat Recovery	0.868	0.000	1.408	0.000	1.730	0.000	1.464	0.000	1.061	0.000	0.600	0.000
Lighting, Interior & Exterior	1.890	0.000	1.957	0.000	3.814	0.000	1.402	0.000	2.116	0.000	1.054	0.000
Plugs, Refrigeration, Other	2.438	0.000	9.269	0.000	2.186	0.000	4.602	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.012	0.000	0.037	0.097	0.016	0.000	0.140	3.438	0.000
Total	7.227	0.016	14.909	0.028	8.864	0.191	8.718	0.117	8.808	0.248	9.987	0.024
ASHRAE 90.1-2019												
Heating, Humidification	0.575	0.017	0.763	0.015	0.000	0.166	0.000	0.051	0.678	0.015	0.000	0.028
Cooling	0.520	0.000	1.403	0.000	1.038	0.000	1.088	0.000	1.349	0.000	0.647	0.000
Fans, Pumps, Heat Recovery	0.794	0.000	1.369	0.000	1.644	0.000	1.333	0.000	1.004	0.000	0.579	0.000
Lighting, Interior & Exterior	1.579	0.000	1.629	0.000	3.104	0.000	1.158	0.000	1.459	0.000	0.901	0.000
Plugs, Refrigeration, Other	2.439	0.000	9.269	0.000	2.186	0.000	4.458	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.012	0.000	0.037	0.097	0.016	0.000	0.140	3.439	0.000
Total	6.817	0.017	14.432	0.027	7.973	0.202	8.134	0.114	8.078	0.248	9.775	0.028
Total Savings	0.411	-0.001	0.477	0.001	0.891	-0.012	0.584	0.003	0.730	0.000	0.213	-0.004

6.0 References

(ASHRAE) ANSI/ASHRAE/IES – American National Standards Institute, American Society of Heating, Refrigerating and Air-Conditioning Engineers, and Illuminating Engineering Society. 2016. *ANSI/ASHRAE/IES 90.1-2016, Energy Standard for Buildings Except Low-Rise Residential Buildings.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.

(ASHRAE) ANSI/ASHRAE/IES – American National Standards Institute, American Society of Heating, Refrigerating and Air-Conditioning Engineers, and Illuminating Engineering Society. 2019. *ANSI/ASHRAE/IES 90.1-2019, Energy Standard for Buildings Except Low-Rise Residential Buildings.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.

Bureau of Labor Statistics. 2021. “Producer Price Indexes.” Washington, D.C. Accessed April 20, 2021 at www.bls.gov/data

Commercial Loan Direct. 2021. “Commercial Mortgage Interest Rates - Nationwide Lending, Mid Balance - Investor/Owner Occupied.” Atlanta, Georgia. Accessed April 20, 2021 at www.commercialloandirect.com/commercial-rates.php

Dodge Data & Analytics. 2020. Construction Research web page [Online]. Available: https://www.construction.com/products/construction-research [Accessed March July 18, 2021].

DOE – U.S. Department of Energy. 2021. *Energy Savings Analysis: ANSI/ASHRAE/IES Standard 90.1-2019.* DOE/EE-2345, U.S. Department of Energy, Washington, D.C. Available at https://www.energycodes.gov/development/determinations

EIA – United States Energy Information Administration. 2021a. *Electric Power Monthly, March 2021.* Energy Information Administration, Washington, D.C. Available at https://www.eia.gov/electricity/monthly/

EIA – United States Energy Information Administration. 2021b. *Natural Gas Monthly, March 2021*. Energy Information Administration, Washington, D.C. Available at https://www.eia.gov/naturalgas/monthly/

EPA. 2014. *Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources (Chapter 1)*. U.S. Environmental Protection Agency, Washington, D.C. Available at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors

EPA. 2020 *AVoided Emissions and geneRation Tool (AVERT), User Manual Version 3.0*. U.S. Environmental Protection Agency, Washington, D.C. Available at https://www.epa.gov/avert/avert-user-manual

EPA. 2021a. *THE EMISSIONS & GENERATION RESOURCE INTEGRATED DATABASE eGRID Technical Guide with Year 2019 Data*. U.S. Environmental Protection Agency, Washington, D.C. Available at https://www.epa.gov/sites/production/files/2021-02/documents/egrid2019_technical_guide.pdf

EPA. 2021b. *Emission Factors for Greenhouse Gas Inventories*. U.S. Environmental Protection Agency, Washington, D.C. Available at https://www.epa.gov/sites/production/files/2021-04/documents/emission-factors_apr2021.pdf

FTA – Federation of Tax Administrators. 2021. "Range of State Corporate Income Tax Rates." Washington, D.C. Accessed April 20, 2021 at https://www.taxadmin.org/assets/docs/Research/Rates/corp_inc.pdf

Fuller SK and SR Petersen. 1995. *Life-Cycle Costing Manual for the Federal Energy Management Program*, NIST Handbook 135. U.S. Department of Commerce, Washington, D.C.

Hart PR and B Liu. 2015. *Methodology for Evaluating Cost-effectiveness of Commercial Energy Code Changes.* PNNL-23923 Rev 1. Pacific Northwest National Laboratory, Richland, WA. Available at https://www.energycodes.gov/sites/default/files/documents/commercial_methodology.pdf

IWG – Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. 2016. *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. Available at https://www.epa.gov/sites/production/files/2016-12/documents/sc_tsd_august_2016.pdf

IWG – Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. 2021. *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990*. Available at https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

Tyler M, R Hart, Y Xie, M Rosenberg, M Myer, M Halverson, C Antonopoulos, and J Zhang. 2021. *National Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019.* PNNL-29940. Pacific Northwest National Laboratory, Richland, WA.

Lei, X., J.B. Butzbaugh, Y. Chen, J. Zhang, and M.I. Rosenberg. 2020. Development of National New Construction Weighting Factors for the Commercial Building Prototype Analyses (2003-2018). PNNL-29787, Pacific Northwest National Laboratory, Richland, WA.

Lavappa P and J Kneifel. 2019. *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis-2019: Annual Supplement to NIST Handbook 135*. National Institute of Standards and Technology, U.S. Department of Commerce, Washington, D.C. Available at https://doi.org/10.6028/NIST.IR.85-3273-34

Mendon VV, A Selvacanabady, M Zhao, and ZT Taylor. 2015. *National Cost-Effectiveness of the Residential Provisions of the 2015 IECC*. PNNL-24240. Pacific Northwest National Laboratory, Richland, WA. Available at www.energycodes.gov/development/residential/iecc_analysis

RealtyRates.com Investor Survey – 1st Quarter 2021 Permanent Financing." Bradenton, Florida. Accessed April 20, 2021 at www.realtyrates.com/commercial-mortgage-rates.html

RS Means. 2020a. *RSMeans Mechanical Cost Data*, 43rd Ed. Construction Publishers & Consultants. Norwell, Massachusetts.

RS Means. 2020b. *RSMeans Building Construction Cost Data*, 78th Ed. Construction Publishers & Consultants. Norwell, Massachusetts.

Tax Foundation. 2020. "State and Local Sales Tax Rates 2020." Washington, D.C. Available at https://taxfoundation.org/state-and-local-sales-tax-rates-2020

Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

www.pnnl.gov

PNNL-31627

Cost-Effectiveness of the 2021 IECC for Residential Buildings in Virginia

July 2021

Victor R Salcido
Yan Chen
YuLong Xie
Zachary T Taylor

U.S. DEPARTMENT OF ENERGY
Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
email: orders@ntis.gov <https://www.ntis.gov/about>
Online ordering: http://www.ntis.gov

PNNL-31627

Cost-Effectiveness of the 2021 IECC for Residential Buildings in Virginia

July 2021

Victor R Salcido
Yan Chen
YuLong Xie
Zachary T Taylor

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99354

Highlights

The 2021 IECC provides cost-effective levels of energy efficiency and performance for residential buildings in Virginia

Moving to the 2021 International Energy Conservation Code (IECC) is cost-effective for both single-family and low-rise multifamily residential buildings in Virginia. The 2021 IECC will provide statewide energy savings of 17.9% across all climate zones compared to the current state energy code. This equates to $ 413 of annual utility bill savings for the average Virginia household. It will reduce statewide CO_2 emissions over 30 years by 28,420,000 metric tons, equivalent to the annual CO_2 emissions of 6,181,000 cars on the road (1 MMT CO_2 = 217,480 cars driven/year). Updating the state energy code based on the 2021 IECC will also stimulate the creation of high-quality jobs across the state. Adopting the 2021 IECC in Virginia is expected to result in homes that are energy efficient, more affordable to own and operate, and based on current industry standards for health, comfort and resilience.

The average expected statewide economic impact (per dwelling unit) of upgrading to the 2021 IECC is shown in the tables below based on cost-effectiveness and carbon metrics established by the U.S. Department of Energy.[1]

Consumer Impact

Metric	Compared to the 2015 IECC with amendments
Life-cycle cost savings of the 2021 IECC	$8,376
Net annual consumer cash flow in year 1 of the 2021 IECC[2]	$250
Annual (first year) energy cost savings of the 2021 IECC ($)[3]	$413
Annual (first year) energy cost savings of the 2021 IECC (%)[4]	17.9%

[1] A weighted average is calculated across building configurations and climate zones.
[2] The annual cash flow is defined as the net difference between annual energy savings and annual cash outlays (mortgage payments, etc.), including all tax effects but excluding up-front costs (mortgage down payment, loan fees, etc.). First-year net cash flow is reported; subsequent years' cash flow will differ due to the effects of inflation and fuel price escalation, changing income tax effects as the mortgage interest payments decline, etc.
[3] Annual energy savings is reported at time zero, before any inflation or price escalations are considered.
[4] Annual energy savings is reported as a percentage of end uses regulated by the IECC (HVAC, water heating, and interior lighting).

Statewide Impact - Emissions

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, $	7,192,000	2,487,000,000
CO_2 emission reduction, Metric tons	56,430	28,420,000
CH_4 emissions reductions, Metric tons	3.10	1,559
N_2O emissions reductions, Metric tons	0.416	209
NOx emissions reductions, Metric tons	28.75	14,480
SOx emissions reductions, Metric tons	40.82	20,560

Statewide Impact – Jobs Created

Statewide Impact	First Year	30 Years Cumulative
Jobs Created -- Reduction in Utility Bills	320	9,514
Jobs Created -- Construction Related Activities	546	16,240

Acronyms and Abbreviations

AVERT	U.S. EPA Avoided Emissions and GeneRation Tool
BC3	Building Component Cost Community
BECP	Building Energy Codes Program
CH_4	Methane
CO_2	Carbon Dioxide
CPI	consumer price index
DOE	U.S. Department of Energy
E.O.	Executive Order
eGRID	EPA Emissions & Generation Resource Integrated Database dataset
EIA	Energy Information Administration
EPA	Environmental Protection Agency
ERI	Energy Rating Index
GHG	greenhouse gas
IAM	Integrated assessment models
ICC	International Code Council
IECC	International Energy Conservation Code
LCC	Life-Cycle Cost
NAHB	National Association of Home Builders
N_2O	Nitrous Oxide
NO_X	Nitrogen Oxides
PNNL	Pacific Northwest National Laboratory
SO_X	Sulfur Oxides

Contents

Figures

Tables

1.0 Cost-Effectiveness Results for the 2021 IECC for Virginia

This section summarizes the cost-effectiveness analysis in terms of three primary economic metrics applicable to the homeowner:

- Life-Cycle Cost (LCC): Full accounting over a 30-year period of the cost savings, considering energy savings, the initial investment financed through increased mortgage costs, tax impacts, and residual values of energy efficiency measures
- Consumer Cash Flow: Net annual cost outlay (i.e., difference between annual energy cost savings and increased annual costs for mortgage payments, etc.)
- Simple Payback Period: Number of years required for energy cost savings to exceed the incremental first costs of a new code, ignoring inflation and fuel price escalation rates

LCC savings is the primary metric established by the U.S. Department of Energy (DOE) to assess the economic impact of residential building energy codes. Simple payback period and the Consumer Cash Flow analysis are reported to provide additional information to stakeholders, including states which have established a range of alternative economic metrics. Both the LCC savings and the year-by-year cash flow values from which it is calculated assume that initial costs are mortgaged, that homeowners take advantage of mortgage interest tax deductions, that individual efficiency measures are replaced with like measures at the end of their useful lifetimes, and that efficiency measures may retain a prorated residual value at the end of the 30-year analysis period.

Societal benefits such as benefits from energy codes as well as reduction of carbon emissions and jobs generated from moving to the 2021 IECC are discussed in Section 5.0.

A complete description of the DOE methodology for assessing the cost-effectiveness of building energy codes is available on energycodes.gov[1].

1.1 Life-Cycle Cost

The Life-Cycle Cost (LCC) analysis computes overall cost savings per dwelling unit resulting from implementing the efficiency improvements of a new energy code. LCC savings is based on the net change in overall cash flows (energy savings minus additional costs) resulting from implementing a new energy code, and balances incremental costs of construction against longer-term energy savings, including consideration for costs of operations and replacements, as needed. LCC savings is a sum over an analysis period of 30 years. Future cash flows, which vary from year to year, are discounted to present values using a discount rate that accounts for the changing value of money over time. LCC savings is the primary economic metric established by DOE for assessing the cost-effectiveness of building energy codes.

Table 1 shows the LCC savings (discounted present value) over the 30-year analysis period for the 2021 IECC compared to the 2015 IECC with amendments.

[1] https://www.energycodes.gov/sites/default/files/documents/residential_methodology_2015.pdf

Table 1. Life-Cycle Cost Savings of the 2021 IECC compared to the 2015 IECC with amendments

Climate Zone	Life-Cycle Cost Savings ($)
3A	7,222
4A	8,675
5A	8,780
State Average	**8,376**

Note: Warm-humid climate zones are labeled "WH"

1.2 Consumer Cash Flow

The Consumer Cash Flow results are derived from the year-by-year calculations that underlie the Life-Cycle Cost savings values shown above. The specific cash flow values shown here allow an assessment of how annual cost outlays are compensated by annual energy savings and the time required for cumulative energy savings to exceed cumulative costs, including both increased mortgage payments and the down payment and other up-front costs.

Table 2 shows the per-dwelling-unit impact of the improvements in the 2021 IECC on Consumer Cash Flow compared to the 2015 IECC with amendments.

Table 2. Consumer Cash Flow from Compliance with the 2021 IECC Compared to the 2015 IECC with amendments

	Cost/Benefit	3A	4A	5A	State Average
A	Incremental down payment and other first costs	$214	$486	$373	$429
B	Annual energy savings (year one)	$339	$448	$426	$426
C	Annual mortgage increase	$74	$168	$129	$148
D	Net annual cost of mortgage interest deductions, mortgage insurance, and property taxes (year one)	$14	$31	$24	$27
E = [B-(C+D)]	Net annual cash flow savings (year one)	$252	$250	$274	$250
F = [A/E]	Years to positive savings, including up-front cost impacts	1	2	2	2

Note: Item D includes mortgage interest deductions, mortgage insurance, and property taxes for the first year. Deductions can partially or completely offset insurance and tax costs. As such, the "net" result appears relatively small or is sometimes even negative.

1.3 Simple Payback Period

The simple payback period is a straightforward metric including only the costs and benefits directly related to the implementation of energy-saving measures associated with a code change. It represents the number of years required for the energy savings to pay for the cost of the measures, without regard for inflation, changes in fuel prices, tax effects, measure replacements, resale values, etc. The simple payback period is useful for its ease of calculation and understandability. Because it focuses on the two primary characterizations of a code change—cost and energy performance—it allows an assessment of cost effectiveness that is easy to compare with other investment options and requires a minimum of input data. DOE reports the simple payback period because it is a familiar metric used in many contexts, and because some states have expressed the desire for this metric. However, because it ignores many of the longer-term factors in the economic performance of an energy-efficiency investment, DOE does not use the payback period as a primary indicator of cost effectiveness for its own decision-making purposes.

Table 3 shows the simple payback period for the 2021 IECC. The simple payback period is calculated by dividing the incremental construction cost by the annual energy cost savings assuming time-zero fuel prices. It estimates the number of years required for the energy cost savings to pay back the incremental cost investment without consideration of financing of the initial costs through a mortgage, the favored tax treatment of mortgages, the useful lifetimes of individual efficiency measures, or future escalation of fuel prices.

Table 3. Simple Payback Period for the 2021 IECC Compared to the 2015 IECC with amendments

Climate Zone	Payback Period (Years)
3A	5.0
4A	8.7
5A	7.0
State Average	**8.1**

2.0 Overview of the Cost-Effectiveness Analysis Methodology

This analysis was conducted by Pacific Northwest National Laboratory (PNNL) in support of the DOE Building Energy Codes Program. DOE is directed by federal law to provide technical assistance supporting the development and implementation of residential and commercial building energy codes. The national model energy codes—the International Energy Conservation Code (IECC) and ANSI/ASHRAE/IES Standard 90.1—help adopting states and localities establish minimum requirements for energy-efficient building design and construction, as well as mitigate environmental impacts and ensure residential and commercial buildings are constructed to modern industry standards.

The current analysis evaluates the cost-effectiveness of the 2021 edition of the IECC, relative to the 2015 IECC with amendments. The analysis covers one- and two-family dwelling units, townhouses, and low-rise multifamily residential buildings covered by the residential provisions of the IECC. The analysis is based on the prescriptive requirements of the IECC. The IECC's simulated performance path (Section 405) and Energy Rating Index (ERI) path (Section 406) are not in the scope of this analysis, as they are generally based on the core prescriptive requirements of the IECC, and due to the unlimited range of building configurations that are allowed. Buildings complying via these paths are generally considered to provide equal or better energy performance compared to the prescriptive requirements, as the intent of these paths is to provide additional design flexibility and cost optimization, as dictated by the builder, designer or homeowner.

The current analysis is based on the methodology by DOE for assessing energy savings and cost-effectiveness of residential building energy codes (Taylor et al. 2015). The LCC analysis perspective described in the methodology appropriately balances upfront costs with longer term consumer costs and savings and is therefore the primary economic metric by which DOE evaluates the cost-effectiveness of building energy codes.

2.1 Estimation of Energy Usage and Savings

In order to estimate the energy impact of residential code changes, PNNL developed a single-family prototype building and a low-rise multifamily prototype building to represent typical new residential building construction (BECP 2012, Mendon et al. 2014, and Mendon et al. 2015). The key characteristics of these prototypes are:

- **Single-Family Prototype:** A two-story home with a roughly 30-ft by 40-ft rectangular shape, 2,376 ft^2 of conditioned floor area excluding the conditioned basement (if any), and window area equal to 15% of the conditioned floor area equally distributed toward the four cardinal directions.
- **Multifamily Prototype:** A three-story building with 18 dwelling units (6 units per floor), each unit having conditioned floor area of 1,200 ft^2 and window area equal to approximately 23% of the exterior wall area (not including breezeway walls) equally distributed toward the four cardinal directions.

These two building prototypes are further expanded to cover four common heating systems (natural gas furnace, heat pump, electric resistance, oil-fired furnace) and four common foundation types (slab-on-grade, heated basement, unheated basement, crawlspace), leading to an expanded set of 32 residential prototype building models. This set is used to simulate the energy usage for typical homes built to comply with the requirements of the 2021 IECC and those built to comply with the requirements of the for one location in each climate zone[1] in the state using DOE's *EnergyPlus™* software, version 9.5 (DOE 2021). Energy savings of the 2021 IECC relative to the 2015 IECC with amendments, including space heating, space cooling, water heating, lighting and plug loads are extracted from the simulation results.

2.2 Climate Zones

Climate zones are defined in ASHRAE Standard 169, as specified in ASHRAE Standard 90.1, and include eight primary climate zones in the United States, the hottest being climate zone 1 and the coldest being climate zone 8. Letters A, B, and C are applied in some cases to denote the level of moisture, with A indicating humid, B indicating dry, and C indicating marine. Figure 3 shows the national climate zones. For this state analysis, savings are analyzed for each climate zone in the state using weather data from a selected city within the climate zone and state, or where necessary, a city in an adjoining state with more robust weather data.

[1] One location is simulated for each combination of climate zone, moisture regime (Moist, Dry, Marine) and humidity designation (Warm-Humid, Not Warm-Humid) that exists in the state.

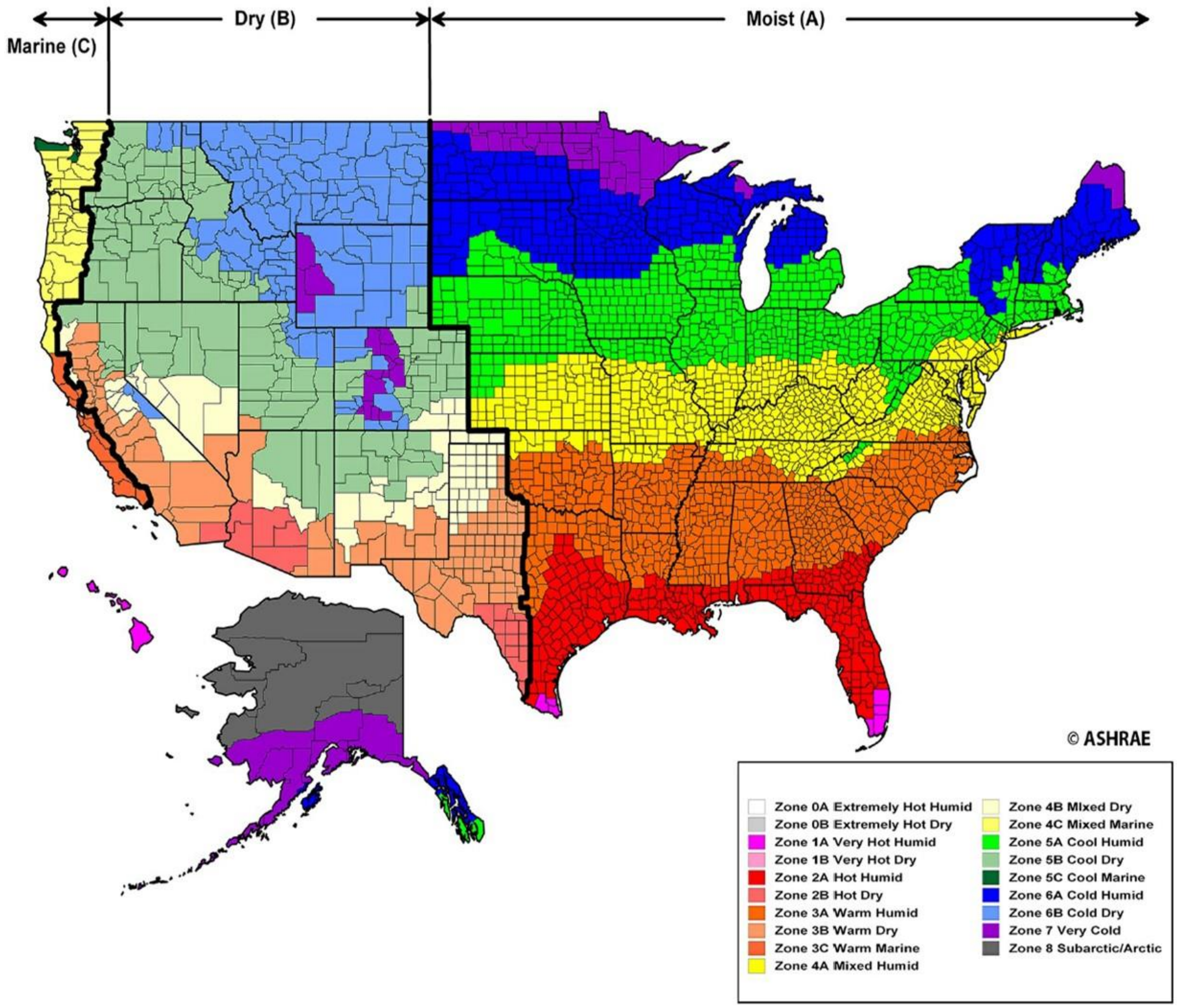

Figure 1. National Climate Zones

2.3 Fuel Prices

The energy savings from the simulation analysis are converted to energy cost savings using the most recent state-specific residential fuel prices from DOE's Energy Information Administration (EIA 2020a, EIA 2020b, EIA 2020c). The fuel prices used in the analysis are shown in Table 4.

Table 4. Fuel Prices used in the Analysis

Electricity ($/kWh)	Gas ($/Therm)	Oil ($/MBtu)
0.122	1.158	2.422

2.4 Financial and Economic Parameters

The financial and economic parameters used in calculating the LCC and annual consumer cash flow are based on the latest DOE cost-effectiveness methodology (Taylor et al. 2015) to represent the current economic scenario. The parameters are summarized in Table 5 for reference.

Table 5. Economic Parameters Used in the Analysis

Parameter	Value
Mortgage interest rate (fixed rate)	3%
Loan fees	1% of mortgage amount
Loan term	30 years
Down payment	12% of home value
Nominal discount rate (equal to mortgage rate)	3%
Inflation rate	1.4%
Marginal federal income tax	12%
Marginal state income tax	5.75%
Property tax	0.74%

2.5 Aggregation Scheme

Energy results, weighted by foundation and heating system type, are provided at the state level and separately for each climate zone within the state. The distribution of heating systems for Virginia is derived from data collected by the National Association of Home Builders data (NAHB 2009) and is summarized in Table 6. The distribution of foundation types is derived from the Residential Energy Consumption Survey data (RECS 2013) and is summarized in Table 7. The single-family and multifamily results are combined for each climate zone in the state and the climate zone results are combined to calculate a weighted average for the state using 2019 new residential construction starts from the 2010 U.S. Census data (Census 2010). The distribution of single- and multifamily building starts is summarized in Table 8.

Table 6. Heating Equipment Shares

Heating System	Share of New Homes (percent)	
	Single-Family	Multifamily
Natural Gas	19.6	19.6
Heat Pump	78.4	78.4
Electric Resistance	1.9	1.9
Oil	0.1	0.1

Table 7. Foundation Type Shares

Foundation Type	Slab-on-grade	Heated Basement	Unheated Basement	Crawlspace
Share of New Homes (percent)	30.8	23.1	11.5	34.6

Table 8. Construction Shares by Climate Zone

Climate Zone	Share of New Homes (percent)	
	Single-Family	Multifamily
3A	68.2	31.8
4A	68.2	31.8
5A	68.2	31.8

3.0 Incremental Construction Costs

In order to evaluate the cost-effectiveness of the changes introduced by the 2021 IECC over the 2015 IECC, PNNL estimated the incremental construction costs associated with these changes. For this analysis, cost data sources consulted by PNNL include:

- Building Component Cost Community (BC3) data repository (DOE 2012)
- Construction cost data collected by Faithful+Gould under contract with PNNL (Faithful + Gould 2012)
- RS Means Residential Cost Data (RSMeans 2020)
- National Residential Efficiency Measures Database (NREL 2014)
- Price data from nationally recognized home supply stores

The consumer price index (CPI) is used to adjust cost data from earlier years to the study year (U.S. Inflation Calculator 2021).

The estimated costs of implementing the prescriptive provisions of the 2021 IECC over the 2015 IECC with amendments are taken from earlier PNNL studies that evaluated the cost-effectiveness (Lucas et al. 2012), (Mendon et.al. 2015) and (Taylor et al. 2019). The national scope costs from those studies are adjusted to reflect local construction costs in using location factors provided by RSMeans (2020). The incremental costs of implementing the provisions of the 2021 IECC over the 2018 IECC are described in National Cost Effectiveness of the Residential Provisions of the 2021 IECC (Salcido et al. 2021).

Table 9 and Table 10 show the incremental construction costs associated with the 2021 IECC compared to the 2015 IECC with amendments for an individual dwelling unit. Table 9 shows results for a house and Table 10 shows results for an apartment or condominium. These have been adjusted using a construction cost multiplier, 0.8873, to reflect local construction costs based on location factors provided by RSMeans (2020).

Table 9. Total Single-Family Construction Cost Increase for the 2021 IECC Compared to the 2015 IECC with amendments ($)

Single-family Prototype House				
Climate Zone	**Crawlspace**	**Heated Basement**	**Slab**	**Unheated Basement**
3A	$1,760	$1,760	$2,216	$1,760
4A	$4,622	$4,622	$5,078	$4,622
5A	$3,424	$3,424	$3,880	$3,424

Table 10. Total Multifamily Construction Cost Increase for the 2021 IECC Compared to the 2015 IECC with amendments ($)[1]

Multifamily Prototype Apartment/Condo				
Climate Zone	Crawlspace	Heated Basement	Slab	Unheated Basement
3A	$1,127	$1,127	$1,194	$1,127
4A	$1,631	$1,631	$1,699	$1,631
5A	$1,433	$1,433	$1,501	$1,433

[1] In the multifamily prototype model, the heated basement is added to the building, and not to the individual apartments. The incremental cost associated with heated basements is divided among all apartments equally.

4.0 Energy Cost Savings

Table 11 and Table 12 show the estimated the annual per-dwelling unit energy costs of end uses regulated by the IECC as well as miscellaneous end use loads, which comprise heating, cooling, water heating, lighting, fans, mechanical ventilation and plug loads that result from meeting the requirements of the 2021 IECC and the 2015 IECC with amendments

Table 11. Annual (First Year) Energy Costs for the 2015 IECC with amendments

Climate Zone	2015 IECC with amendments						
	Heating	**Cooling**	**Water Heating**	**Lighting**	**Fans**	**Vents**	**Total**
3A	$534	$234	$282	$171	$85	$42	$2,213
4A	$597	$267	$292	$171	$105	$42	$2,337
5A	$956	$128	$344	$171	$107	$42	$2,612
State Average	**$585**	**$259**	**$290**	**$171**	**$101**	**$42**	**$2,313**

Table 12. Annual (First Year) Energy Costs for the 2021 IECC

Climate Zone	2021 IECC						
	Heating	**Cooling**	**Water Heating**	**Lighting**	**Fans**	**Vents**	**Total**
3A	$460	$205	$106	$150	$77	$21	$1,883
4A	$450	$223	$110	$150	$83	$21	$1,902
5A	$830	$107	$132	$150	$94	$21	$2,198
State Average	**$454**	**$219**	**$110**	**$150**	**$82**	**$21**	**$1,899**

Table 13 shows the first-year energy cost savings as both a net dollar savings and as a percentage of the total regulated end use energy costs. Results are weighted by single- and multifamily housing starts, foundation type, and heating system type.

Table 13. Total Energy Cost Savings (First Year) for the 2021 IECC Compared to the 2015 IECC with amendments

Climate Zone	First Year Energy Cost Savings	First Year Energy Cost Savings (percent)
3A	$329	14.9%
4A	$435	18.6%
5A	$414	15.8%
State Average	**$413**	**17.9%**

5.0 Societal Benefits

5.1 Benefits of Energy Codes

It is estimated that by 2060, the world will add 2.5 trillion square feet of buildings, an area equal to the current building stock. As a building's operation and environmental impact is largely determined by upfront decisions, energy codes present a unique opportunity to assure savings through efficient building design, technologies, and construction practices. Once a building is constructed, it is significantly more expensive to achieve higher efficiency levels through later modifications and retrofits. Energy codes ensure that a building's energy use is included as a fundamental part of the design and construction process; making this early investment in energy efficiency will pay dividends to residents of Virginia for years into the future.

5.2 Greenhouse Gas Emissions

The urban built environment is responsible for 75% of annual global greenhouse gas (GHG) emissions while buildings alone account for 39%.[1] On January 20, 2021, President Biden issued Executive Order (E.O.) 13990,[2] which noted that it is essential that agencies capture the full costs of greenhouse gas emissions as accurately as possible, including by taking global damages into account and that doing so facilitates sound decision-making, recognizes the breadth of climate impacts, and supports the international leadership of the United States on climate issues.

While carbon dioxide emissions represent the largest share of greenhouse gas emissions, building electricity use and fossil fuel consumption on site also contribute to the release of other emissions, two of which, methane (CH_4) and nitrous oxide (N_2O) are significant greenhouse gases in their own right.

For natural gas and for fuel oil combusted on site, emission metrics are developed using nationwide emission factors from U.S. Environmental Protection Agency publications for CO_2, NOx, SO_2, CH_4 and N_2O (EPA 2014). For electricity, marginal carbon emission factors are provided by the U.S. Environmental Protection Agency (EPA) AVoided Emissions and GeneRation Tool (AVERT) version 3.0 (EPA 2020). The AVERT tool forms the basis of the national marginal emission factors for electricity also published by EPA on its Greenhouse Gas Equivalencies Calculator website and are based on a portfolio of energy efficiency measures examined by EPA. AVERT is used here to provide marginal CO_2 emission factors at the State level.[3] AVERT also provides marginal emission factor estimates for gaseous pollutants

[1] Architecture 2030

[2] Exec. Order No. 13990, 86 Fed. Reg. 7037 (January 20, 2021) <https://www.federalregister.gov/documents/2021/01/25/2021-01765/protecting-public-health-and-the-environment-and-restoring-science-to-tackle-the-climate-crisis>

[3] AVERT models avoided emissions in 14 geographic regions of the 48 contiguous United States and includes transmission and distribution losses. Where multiple AVERT regions overlap a state's boundaries, the emission factors are calculated based on apportionment of state electricity savings by generation across generation regions. The most recent AVERT 3.0 model uses EPA emissions data for generators from 2019. Note that AVERT estimates are based on marginal changes to demand and reflect current grid generation mix. Emission factors for electricity shown in Table 14 do not take into account long term policy or technological changes in the regional generation mix that can impact the marginal emission benefits from new building codes.

associated with electricity production, including NOx and SO_2 emissions. While not considered significant greenhouse gases, these are EPA tracked pollutants. The current analysis uses AVERT to provide estimates of corresponding emission changes for NOx and SO_2 in physical units but does not monetize these.

AVERT does not develop associated marginal emissions factors for CH_4 or N_2O. To provide estimates for the associated emission reductions for CH_4 and N_2O, this report uses emission factors separately provided through the U.S. Environmental Protection Agency (EPA) Emissions & Generation Resource Integrated Database (eGRID) dataset. eGRID is a comprehensive source of data on the environmental characteristics of almost all electric power generated in the United States and the emission characteristics for electric power generation for each of the above emissions can also be found aggregated down to the state level in eGRID (EPA 2021a). The summary emission factor data provided by eGRID does not provide marginal emission factors, but instead summarizes emission factors in terms of total generation emission factors and non-baseload generation emission factors. Non-baseload emission factors established in eGRID are developed based on the annual load factors for the individual generators tracked by the EPA (EPA 2021b). Because changes in building codes are unlikely to significantly impact baseload electrical generators, the current analysis uses the 2019 non-baseload emission factors established in eGRID by state to estimate CH_4 or N_2O emission reductions due to changes in electric consumption.

Table 14 summarizes the marginal carbon emission factors available from AVERT, eGRID and the EPA Greenhouse Gas Equivalencies Calculator.

Table 14. Greenhouse Gas Emission Factors for Virginia by Fuel Type

GHG	Electricity lb/MWh	Natural Gas (lb/mmcf)	Fuel Oil (lb/1000 gal)
CO_2	1,567	120,000	23,000
SO_2	1.194	0.6	12
NO_X	0.771	96	19
N_2O	0.012	0.23	0.45
CH_4	0.093	2.3	0.7

Table 15 shows the annual first year and projected 30-year energy cost savings. This table also shows first year and projected 30-year greenhouse gas (CO_2, CH_4, and N_2O) emission reductions, in addition to NOx and SO_2 reductions.

Table 15. Societal Benefits of the 2021 IECC

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, $	7,192,000	2,487,000,000
CO_2 emission reduction, Metric tons	56,430	28,420,000
CH_4 emissions reductions, Metric tons	3.10	1,559
N_2O emissions reductions, Metric tons	0.416	209
NOx emissions reductions, Metric tons	28.75	14,480
SOx emissions reductions, Metric tons	40.82	20,560

5.3 Jobs Creation through Energy Efficiency

Energy-efficient building codes impact job creation through two primary value streams:

1. Dollars returned to the economy through reduction in utility bills and resulting increase in disposable income, and;
2. An increase in construction-related activities associated with the incremental cost of construction that is required to produce a more energy efficient building.

When a home or building is built to a more stringent energy code, there is the long-term benefit of the home or building owner paying lower utility bills.

- This is partially offset by the increased cost of that efficiency, establishing a relationship between increased building energy efficiency and additional investments in construction activity.
- Since building codes are cost effective, (i.e., the savings outweigh the investment), a real and permanent increase in wealth occurs which can be spent on other goods and services in the economy, just like any other income, generating economic benefits in turn creating additional employment opportunities.

Table 16 also shows the number of jobs created because of efficiency gains in the 2021 IECC. Results are weighted by single- and multifamily housing starts, foundation type, and heating system type.

Table 16. Jobs Created from the 2021 IECC

Statewide Impact	First Year	30 Years Cumulative
Jobs Created -- Reduction in Utility Bills	320	9,514
Jobs Created -- Construction Related Activities	546	16,240

6.0 References

BECP. 2012. Residential Prototype Building Models developed by DOE's Building Energy Codes Program. Available at http://www.energycodes.gov/development/residential/iecc_models/

U.S. Inflation Calculator. 2021. *Consumer Price Index Data from 1913 to 2021*. Coin News Media Group LLC. Available at https://www.usinflationcalculator.com/inflation/historical-inflation-rates/

U.S. Census Bureau. 2010. *Characteristics of New Housing*. U.S. Census Bureau, Washington, D.C. Available at http://www.census.gov/construction/chars/completed.html

DOE. 2012. *Building Component Cost Community*. U.S. Department of Energy, Washington, D.C. Available at http://bc3.pnnl.gov/

DOE. 2015. *Determination Regarding Energy Efficiency Improvements in the 2015 International Energy Conservation Code (IECC)*. U.S. Department of Energy, Washington, D.C. Available at http://www.energycodes.gov/sites/default/files/documents/2015_IECC_Determination.pdf

DOE. 2021. *EnergyPlus Energy Simulation Software, Version 9.5*. U.S. Department of Energy, Washington, DC. Available at https://energyplus.net/downloads

EIA. 2020a. *Table 5.3. Average Price of Electricity to Ultimate Customers*. U.S. Energy Information Administration, Washington DC. Available at https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_3

EIA. 2020b. *Natural Gas*. U.S. Energy Information Administration, Washington D.C. Available at https://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PRS_DMcf_a.htm

EIA. 2020c. *Natural Gas Heat Content*. U.S. Energy Information Administration, Washington D.C. Available at https://www.eia.gov/dnav/ng/ng_cons_heat_a_EPG0_VGTH_btucf_a.htm

EPA. 2014. *Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources (Chapter 1)*. U.S. Environmental Protection Agency, Washington, D.C. Available at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors

EPA. 2020 *AVoided Emissions and geneRation Tool (AVERT), User Manual Version 3.0*. U.S. Environmental Protection Agency, Washington, D.C. Available at https://www.epa.gov/avert/avert-user-manual

EPA. 2021a. *THE EMISSIONS & GENERATION RESOURCE INTEGRATED DATABASE eGRID Technical Guide with Year 2019 Data*. U.S. Environmental Protection Agency, Washington, D.C. Available at https://www.epa.gov/sites/production/files/2021-02/documents/egrid2019_technical_guide.pdf

EPA. 2021b. *Emission Factors for Greenhouse Gas Inventories*. U.S. Environmental Protection Agency, Washington, D.C. Available at https://www.epa.gov/sites/production/files/2021-04/documents/emission-factors_apr2021.pdf

Faithful + Gould. 2012. *Residential Energy Efficiency Measures: Prototype Estimate and Cost Data*. Faithful+Gould for Pacific Northwest National Laboratory. Available at http://bc3.pnnl.gov/sites/default/files/Residential_Report.pdf

ICC. 2014. *2015 International Energy Conservation Code*. International Code Council, Washington, DC. Available at http://codes.iccsafe.org/app/book/toc/2015/I-Codes/2015%20IECC%20HTML/index.html

ICC. 2017. *2018 International Energy Conservation Code*. International Code Council, Washington, DC. Available at https://shop.iccsafe.org/codes/2018-international-codes-and-references/2018-international-energy-conservation-code/2018-international-energy-conservation-coder.html

IWG – Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. 2016. *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. Available at https://www.epa.gov/sites/production/files/2016-12/documents/sc_tsd_august_2016.pdf

IWG – Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. 2021. *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990*. Available at https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

Lucas R.G., Z.T. Taylor, V.V. Mendon, and S.G. Goel. 2012. *National Energy and Cost Savings for New Single- and Multifamily Homes: A Comparison of the 2006, 2009 and 2012 Editions of the IECC*. Pacific Northwest National Laboratory, Richland, Washington. Available at https://www.energycodes.gov/sites/default/files/documents/NationalResidentialCostEffectiveness.pdf

Mendon V.V. and Z.T. Taylor. 2014. *Development of Residential Prototype Building Models and Analysis System for Large-Scale Energy Efficiency Studies Using EnergyPlus*. 2014 ASHRAE/IBPSA-USA Building Simulation Conference, Atlanta, GA.

Mendon V.V., A. Selvacanabady, M. Zhao, and Z.T. Taylor. 2015. *National Cost-Effectiveness of the Residential Provisions of the 2015 IECC*. Pacific Northwest National Laboratory, Richland, Washington. Available at https://www.energycodes.gov/sites/default/files/documents/2015IECC_CE_Residential.pdf

NREL. 2014. *National Residential Efficiency Measures Database*. National Renewable Energy Laboratory, Golden, Colorado. Available at http://www.nrel.gov/ap/retrofits/

NAHB. 2009. *Builder Practices Reports*. National Association of Home Builders, Upper Marlboro, Maryland. Available at http://www.homeinnovation.com/trends_and_reports/data/new_construction

RECS – Residential Energy Consumption Survey. 2013. *2009 RECS Survey Data*. U.S. Energy Information Administration. Washington D.C. Available at https://www.eia.gov/consumption/residential/data/2009/

RSMeans. 2020. *2020 RS Means Residential Cost Data*. Construction Publishers & Consultants. Norwell, MA. Available at http://www.rsmeans.com/

Salcido V.R., Y Chen, Y Xie, and ZT Taylor. 2021. *National Cost Effectiveness of the Residential Provisions of the 2021 IECC*. Pacific Northwest National Laboratory, Richland Washington. Available at https://www.energycodes.gov/sites/default/files/documents/2018IECC_CE_Residential.pdf

Taylor Z.T., V.V. Mendon, and N. Fernandez. 2015. *Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes*. Pacific Northwest National Laboratory, Richland, Washington. Available at https://www.energycodes.gov/sites/default/files/documents/residential_methodology_2015.pdf

Taylor Z.T., V.V. Mendon, M. Zhao, and B. Liu. 2019. *Energy Savings Analysis: 2018 IECC for Residential Buildings*. Pacific Northwest National Laboratory, Richland, Washington. Available at https://www.energycodes.gov/sites/default/files/documents/EERE-2018-BT-DET-0014-0008.pdf

Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

www.pnnl.gov

Commonwealth of Virginia
Department of Housing and Community Development

Re: 2021 Code Development Cycle
Dated: December 22, 2021

We submit these written comments for the record in the 2021 Code Development Cycle, pursuant to the Notices of Intended Regulatory Action (NOIRA) approved by the Board of Housing and Community Development (BHCD) on October 25, 2021 and published in the Virginia Register of Regulations on November 22, 2021.

We represent solar installation companies and organizations that provide and install rooftop solar facilities for residential and commercial customers throughout the Commonwealth of Virginia. We are addressing IRC Code provision R324.6.1 that pertains to access (pathways) to rooftops for fire fighting purposes, and requirements that go beyond what is needed for safety to become impediments to solar installations.

Setbacks are meant for safety and accessibility for firemen to do their work. The code is written in terms that refer to the distance from the edge of the roofline to the side of the nearest solar panel. But across-the-board requirements that are are stated merely as inches-of-width, without regard to where such set-backs would be placed and why, do not create safer conditions. Of course it's good practice to have a setback on roofs where firemen could have to operate in case of emergency, but what about the roofs where fire fighters would never walk?

Virginia has adopted a statutory mandate to encourage installation of rooftop solar and eliminate impediments to doing that. On the other hand, it has fire and safety requirements. The Code must balance those two policy goals and legal mandates. A provision that creates greater impediments to solar would undercut the solar imperative for no safety gain.

In 2014, our industry encountered a fire code setback issue in Arlington. We contacted the state, and the Commonwealth's Department of Housing and Community Development addressed the issue as follows:

"Chapter 23 of the IRC [International Residential Code] regulates the installation of residential photo voltaic roof systems and requires them to be installed in accordance with NFPA 70 (NEC) and the manufacturer's installation instructions. Specifically the IRC does nor reference the Fire Code, therefor photo voltaic requirements set forth in the Fire Code are not applicable to one and two family dwellings that fall within the scope of the IRC."

Aside from the issue of applicability of R324.6.1 to residential rooftop installations, this statement from the Commonwealth indicates the balance that the state brings to the issue of impediments to solar installations versus safety measures. And this was before the adoption by the 2020 session of the General Assembly of additional mandates to further solar installations, including the Virginia Clean Economy Act which made promotion and installation of solar facilities a state-wide priority and mandate.

Therefore, we believe the existing Virginia code must be modified in order to capture the proper, and intended balance, as follows:

IRC Code R324.6.1 Pathways. O***ne*** pathway of 18 inches width, on separate roof planes from lowest roof edge to ridge shall be provided on all buildings. One pathway shall be provided on the street or driveway side of the roof. For each roof plane with a photovoltaic array, a pathway of 18 inches shall be provided from the lowest roof edge to ridge on the same roof plane as the photovoltaic array, on an adjacent roof plane, or straddling the same and adjacent roof planes *i*f the adjacent roof plane has a photovoltaic array. If the adjacent roof plane does not have a photovoltaic array, **then no pathway is required.** Pathways shall be over areas capable of supporting fire fighters accessing the roof. Pathways shall be located in areas with minimal obstructions such as vent pipes, conduit, or mechanical equipment.

Ipsun Solar, Herve Billiet CEO

Convert Solar, Nolie Diakoulas

Solar United Neighbors, Aaron Sutch

Contacts:

Alan Larsen, alarsen120@aol.com
Nolie Diakoulas, nolie@convert-solar.com
Aaron Sutch, aaron@solarunitedneighbors.org