Regulatory Impact Analysis

Energy Efficiency Standards

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Summary of Notice and Analysis

This Notice follows procedures established by the Energy Independence and Security Act of 2007 for the U.S. Department of Housing and Urban Development (HUD) and the U.S. Department of Agriculture (USDA) to update energy efficiency standards through revisions to the International Energy Conservation Code (IECC) for single-family and low-rise multifamily buildings and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)/ANSI/IES Standard 90.1 (ASHRAE 90.1) for mid- to high-rise multifamily buildings. The last updates to the IECC and ASHRAE 90.1 for HUD and USDA were issued in 2015 and revised the standards to the 2009 IECC and ASHRAE 90.1-2007. The current Notice adopts the most current industry standards at the time of publication, the 2021 IECC and ASHRAE 90.1-2019.[1]

There are two primary benefits of adopting energy-saving building codes: a private surplus for residents in the form of lower energy costs and the external social value of reducing the emission of greenhouse gases (GHGs). The emission of greenhouse gases which create collective harm represents a classic market externality invoking the need for public intervention. The emission of greenhouse gases including carbon dioxide, methane, and nitrous oxide, largely produced from the burning of fossil fuels, like coal, oil, and natural gas, causes a greenhouse effect which creates global warming. While the earth's climate has fluctuated throughout its history, the current rate of global warming is unprecedented over millennia and is tied to human industrial activities starting from the mid-20th century (NASA, n.d.). These industrial activities have raised atmospheric carbon dioxide levels from 280 to 417 parts per million over the last 151 years.

Many of the effects of human-caused global warming endure for centuries. These effects include accelerating sea level rise, longer heat waves, heavier precipitation events, and longer, more frequent, and more intense hurricanes. These changes incur costs, including disruptions and damages to critical infrastructure and property from more frequent and intense extreme events; negative impacts on regional economies and industries that depend on natural resources or favorable climate conditions, such as agriculture, tourism, and fisheries; and changes in energy system costs, through reduced efficiency in power generation and increasing energy demand (USGRP, 2017).

An analysis of the social costs of carbon and other greenhouse gases is not specifically required for the affordability or availability analysis specified under EISA (the primary analysis for that purpose focuses on energy and cost savings accruing directly to the property owner or resident), but the social costs of emissions are relevant to the larger economic costs and benefits required for a regulatory impact analysis. The avoided costs of emissions from adopting the minimum energy standards specified in the Notice can and should be incorporated in the regulatory impact analysis, and do not affect, or undermine, the underlying affordability or availability findings of the Notice.

The Regulatory Impact Analysis discusses the private and public impacts of adopting the latest standards separately, provides average unit-level estimates of the costs of different incremental changes, and aggregates these effects across the affected HUD and USDA programs. We quantify three effects of adopting the new energy codes: the incremental cost of compliance, the private (or internal) benefits of reducing energy bills, and the public (or external) benefits from reducing damages due to GHG emissions. Most of the estimates of the incremental effects are derived from the Pacific Northwest

[1] Both the IECC and ASHRAE 90.1 are updated every three years. See Figure 1.

National Laboratory (PNNL) engineering studies of the building energy codes. These estimates are adjusted by HUD and USDA to reflect the specifics of HUD and USDA programs, OIRA requirements for economic analyses, existing state-level minimum energy standards, and even assumptions concerning the degree of market failure in the provision of energy-efficient housing.

Estimated Aggregate Costs

In the first year of implementation, based on a three-year average of construction levels between 2019 and 2021, we estimate that approximately 150,000 newly built units will be affected by IECC, and about 17,000 units by ASHRAE 90.1, for a total of about 170,000 units in a typical year. Our aggregate results indicate upfront costs for one cohort of $553 million for the IECC update and $7 million for the ASHRAE update, for a total of $560 million per cohort. Who bears the cost depends upon the extent to which construction costs are passed from builders to buyers. The temporal impact depends on the cost of credit. Construction loans allow builders to spread construction costs over time, and mortgage loans allow homebuyers to do the same. The aggregate *annualized* costs are estimated to be approximately $27.4 million at a discount rate of 3 percent and $41.6 million at a discount rate of 7 percent, with a time horizon of 30 years.[2]

Aggregate Energy Savings

The projected energy savings are expected to be as high as $74.2 million annually for one cohort, including $73.1 million from the IECC update and $1.1 million from the ASHRAE update. The private gain is assumed to manifest itself in lower energy bills, increased comfort, or both. We explore scenarios for the IECC in which the surplus private gains may not be achieved through minimum energy standards.

For comparison with the upfront incremental costs for a single year's cohort of housing, which is estimated at $560 million, the present value of the internal efficiency gains over 30 years is estimated to be $1.48 billion at a 3 percent discount rate and $972 million at a 7 percent discount rate.

Reduction of Greenhouse Gas Emissions

The primary public benefits of reducing energy consumption are the avoided damage from reduced greenhouse gas emissions. The estimates vary based on assumptions concerning the value of the marginal social cost of greenhouse gases and the size of the rebound effect (the extent to which increased technical efficiency leads to a less-than-proportional reduction in energy savings due to a marginal increase in energy consumption). Aggregate estimates for one cohort range from $1.6 million to $5.0 million annually for mid-range estimates, to as high as $15.3 million annually for the upper-range estimate. The present value of reduced damages over 30 years at a 3 percent discount rate[3] for one cohort would be $79 million for our mid-range estimates.

Dynamics of Annual Incremental Impacts

The annual effects of the updated minimum energy standards will accumulate across annual cohorts as more energy-efficient units are put in place in future years. However, the incremental impact of every successive cohort is expected to wane as states close the gap between the state and federal minimum

[2] The "annualized" cost is a constant annual cost calculated for a specific present value of discounted costs over a given time horizon. Annualized costs are higher when the discount rate is higher.

[3] Guidance on the use of discount rates advises that 3 percent be used as a social rate of time preference, sometimes referred to as the consumption discount rate, while the higher 7 percent is a rough measure of the return to capital.

standards. As states adopt minimum energy standards at least as strict as the IECC 2021 and ASHRAE-90.1 2019, then the HUD-USDA minimum standards will no longer impose an incremental impact on units built in those states.[4] As industry voluntarily adopts the practices prescribed in IECC 2021 or ASHRAE-90.1 2019, the impact of the Notice will diminish because it will alter the behavior of fewer developers. By this logic, we would expect the annual impacts to be at their greatest in the first year of implementation.

RIA Methodology and Organization

This analysis is organized to describe the derivation of these estimates and explain in detail how the monetized results could vary.

The "Background" section describes the Energy Independence and Security Act of 2007 and trends in state level minimum energy standards.

The "Need for Notice" section discusses research on the theory and evidence for market barriers to energy-efficient investment. Primary motivations for requiring the construction of energy efficiency are minimizing the externalities of energy consumption, the possibility that there are unexploited private gains from energy efficiency due to market barriers, the potential for better managing HUD-assisted rental property, and the imperative of complying with statute.

The "Data" section provides information concerning the programs affected by the minimum energy standards.

We provide different sections to discuss our approach to measuring the update to the IECC and ASHRAE 90.1. The IECC applies to single-family homes and low-rise multifamily, while ASHRAE 90.1 applies to mid- or high-rise multifamily housing.

The "Analysis of Update to 2021 IECC" section presents estimates based on PNNL for the incremental energy savings and construction costs for an update from the 2009 IECC and from the 2018 IECC (to model compliance in states that have adopted standards closer to the 2018 IECC). The RIA discusses a wide range of assumptions concerning the calculation of present value, including project lifetime, energy price trends, and discount rates. The IECC section also presents results on how the net present value of the investment could vary by climate zone, alternative cost estimates, the size of the units, and FHA mortgage loans for homebuyers. Aggregate results for incremental costs and energy efficiency gains are presented at the end of this section.

The "Analysis of Update to ASHRAE 90.1" section describes the incremental impacts for mid-rise rental housing. A variety of cost estimates are considered and aggregated across new construction. The estimates are based on, but not equivalent to, those of PNNL.

The "Benefits: Reduction of Greenhouse Gas Emissions" section explores the reduction of damages from emissions of carbon dioxide, methane, and nitrous oxide through improving the energy efficiency of HUD- and USDA-assisted new construction. Another section, "Benefits of Health and Safety," provides a qualitative review of the increase in well-being from greater energy security.

[4] For example, currently California, Connecticut, Vermont, and Washington have minimum energy standards equivalent to IECC 2021. See https://www.energycodes.gov/state-portal.

The “Impact on the Availability of Affordable Housing” section is the one part of this analysis that is statutorily required by EISA 2007 for HUD and USDA to consider prior to adoption of the most recent energy codes. Our fundamental finding is that under certain conditions, minimum energy standards could deter the construction of affordable housing, but on average we do not expect a reduction of new construction to be an outcome. Homebuyers and renters who are disadvantaged will likely substitute to the more plentiful supply of existing housing. Furthermore, there will be an economic gain in situations where there are market barriers to energy efficiency.

The “Equity impacts” section explores similar questions of affordability and concludes that energy efficiency could be more advantageous for low-income households, but only for those that consume energy relatively intensively.

The “Compliance” section describes some of the challenges likely to be encountered in enforcing the standards. The “Discussion of Alternatives” section mentions some alternatives that do not promote energy efficiency by as much as the proposed update but are less costly. Our “Conclusion” summarizes the results of the analysis. “References” provide a bibliography of all the research concerning energy and housing that we consulted for this analysis.

Appendices provide greater detail. Appendix A presents tables of estimates of new construction by program, used for calculating the aggregate impacts. Appendix B presents an analysis of how HUD chose to adjust PNNL estimates for homes that were significantly different in size from their model homes. Appendix C describes the present value multipliers used in the analysis. Appendix D discusses the National Association of Home Builders’ (NAHB) estimate of incremental construction costs and attempts to resolve the difference with PNNL’s estimates. Appendix E describes the derivation of the cost-incidence result used in the availability analysis. Appendix F presents the data used to develop the aggregate impact of the IECC update. Appendix G considers energy savings under different scenarios of market barriers of energy efficiency. Appendix H shows the annual estimates of the marginal social cost of carbon emissions.

Background

The Energy Independence and Security Act of 2007 (EISA) establishes procedures for HUD and USDA to adopt periodic revisions to the IECC and to ASHRAE 90.1 energy codes. The revisions at hand are the most recently published IECC and ASHRAE 90.1 standards: 2021 IECC for single-family housing and multifamily housing up to three stories, and ASHRAE 90.1-2019 for multifamily housing over three stories.

These revisions cover housing specified in the statute: new construction of single-family and HUD multifamily housing subject to mortgages insured under the National Housing Act or by the Secretary of Agriculture under Title V of the Housing Act of 1949, as well as new construction and rehabilitation of public and assisted housing funded by HOPE VI.

Covered Programs

Covered HUD programs include public housing, Section 202, Section 811, Rental Assistance Demonstration (RAD), Project-Based Vouchers (PBVs), FHA single-family and multifamily mortgage insurance programs, HOME, and Housing Trust Fund. The largest program affected by far is FHA-insured single-family mortgages.

Covered USDA programs include Section 502 guaranteed and direct loans and the Section 523 Mutual Self-Help Loan. The largest USDA program affected is Section 502 guaranteed loans. While USDA supports the construction of multifamily housing, it is excluded from the statute.

HUD and USDA's current minimum energy efficiency standards implemented prior to this Notice were published in a Final Determination of Affordability and Availability by HUD and USDA on May 6, 2015, which established the 2009 IECC as the minimum standard for new single-family housing built with HUD or USDA assistance or insurance or low-rise multifamily housing built with HUD assistance or insurance, and ASHRAE 90.1-2007 for HUD-assisted mid-rise and high-rise multifamily properties over three stories.

Current State Adoption

Most states and some localities have adopted their own energy efficiency codes, many of which exceed these minimum standards. The majority of states adopt versions of the IECC and ASHRAE 90.1, but some issue amendments which weaken the codes, making them more comparable to earlier versions of the code. Some states have home rule policies, where no statewide code exists and building codes are solely enacted at the local level. Other localities have also adopted their own standards.

Figure 1 shows the distribution of state and territory adoption of IECC- and ASHRAE-equivalent standards, as determined by the U.S. Department of Energy (DOE).

Figure 1. Distribution of State and Territory Adoption of IECC and ASHRAE 90.1 Standards

IECC* Single Family and Low-Rise Multifamily		**ASHRAE 90.1* Mid-Rise and High-Rise Multifamily**	
\Year	**Number of States**	**Year**	**Number of States**
IECC 2021	3	ASHRAE 90.1 - 2019	6
IECC 2018	9	ASHRAE 90.1 - 2016	2
IECC 2015	2	ASHRAE 90.1 - 2013	19
IECC 2012	0	ASHRAE 90.1 - 2010	6
IECC 2009	26	ASHRAE 90.1 - 2007	8
Less stringent than IECC 2009, No Statewide Code or Home Rule	11	Less stringent than ASHRAE 90.1-2007, No Statewide Code or Home Rule	10

* As of March 31, 2022

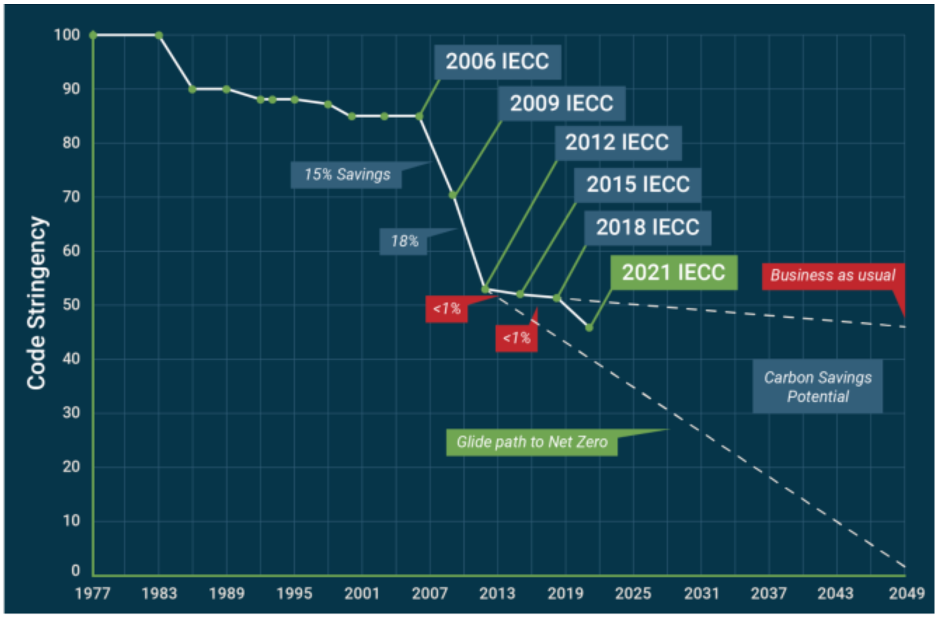
Source: Office of Energy Efficiency and Renewable Energy, DOE, Status of Energy Code Adoption. https://www.energycodes.gov/status

States are not required to adopt these codes. Accordingly, there is typically a lag time between the publication of the code and voluntary adoption by states or home rule jurisdictions. The U.S. Energy Information Administration (EIA) has published research on state code compliance over time. By analyzing components of state codes tracked by the DOE Building Energy Code Program, the Building Code Assistance Project (BCAP), and the Online Code Environment and Advocacy network (OCEAN), the EIA estimated that 100 percent nationwide compliance with the 2009 IECC (or equivalent) would not be attained until 2017, or until 2022 with ASHRAE 90.1-2007 (EIA, 2017). Note that Figure 1 shows that as of March 2022, 26 states have yet to adopt codes equivalent to or higher than the 2009 IECC.

IECC: Single Family and Low-Rise Multifamily

The IECC was developed by the International Code Council, which develops the most widely adopted set of building codes used globally. The code establishes a baseline for energy efficiency by setting minimum performance standards for new construction of a structure's building envelope, mechanical systems, lighting systems, and service water heating systems in homes and commercial businesses, including standards for walls, floors, ceilings, lighting, windows, doors, duct leakage, and air leakage. The IECC is updated every three years through an established code development and consensus process of experts.

Figure *2*. Historic (EISA) and Projected Energy Efficiency Improvements of the IECC



Source: [*https://web.archive.org/web/20211206202136/https://energyefficientcodes.org/iecc/*](https://web.archive.org/web/20211206202136/https://energyefficientcodes.org/iecc/)

The IECC was created in 2000 from its predecessor, the Council of American Building Officials (CABO) Model Energy Code. In 2009, the Energy-Efficient Codes Coalition lobbied for a 30 percent energy efficiency boost; these efforts were halted in the 2015 and 2018 code cycles, but the 2021 update resumed the previous trajectory (see Figure *2*).

In addition to the requirements of state-specific minimum energy codes, state housing finance agencies, which administer the Low-Income Housing Tax Credit (LIHTC), often require or provide incentives for developers to build to a higher standard than the prevailing state code.[5] The construction of many HUD-assisted or financed multifamily projects receive LIHT). To the extent possible, this analysis accounts for this overlap and the higher standards, but due to incomplete data on the overlap, this analysis may underestimate the number of HUD-assisted and insured properties that build to a higher energy standard as required or incentivized by competitive LIHTC Qualified Allocation Plans (QAPs). It is also

[5] For example, in Alaska, which does not have a statewide code, all state assisted properties must comply with the state Building Energy Efficiency Standards (BEES), which currently consists of the 2018 IECC and ASHRAE 90.1-2016. Other state Qualified Action Plans (QAPs) set green building standards as requirements or strongly incentivize such standards.

possible that developers of affordable housing who build both LIHTC and non-LIHTC assisted housing may choose to build the non-LIHTC housing to the higher energy standards for marketing purposes or other motivations. Green Mortgage Insurance Premiums for FHA multifamily mortgages present a similar scenario. This incentive reduces mortgage insurance premiums for multifamily properties that meet one of several eligible green building certifications from entities, including LEED, ENERGY STAR, and others, as well as a certain ENERGY STAR benchmarking score.[6] Developers who are already building to these standards to qualify for reduced MIPs may see lower or nonexistent incremental costs and benefits from this notice.

Need for Notice

There are two justifications for a policy that requires minimum energy efficiency standards for housing: 1) reducing negative externalities from the consumption of energy and 2) the existence of market barriers to the supply of energy-efficient housing. Negative externalities of consumption will be present when there are public costs to energy consumption that are not internalized in the price paid by consumers. A minimum energy standard on new construction is not the most direct means of addressing a negative consumption externality. However, given the lack of alternatives, a carefully considered energy standard is a close second-best to charging a price equal to the social cost. Separate to the oversupply of emissions, there is the possibility of an undersupply of energy-efficient housing when markets do not provide a clear and direct incentive to builders, sellers, and buyers of housing that rewards conservation. The direct implication of underinvestment would be a private loss to residents of housing in the form of higher energy costs. Allcott and Greenstone (2012) find that a minimum standard can be a first best solution for addressing such a market failure as long as the standard is flexible and properly targeted. There is a nuanced consensus that building codes are successful in reducing energy consumption in buildings (Gillingham et al., 2018).[7] Still, HUD and USDA are aware that the heterogeneity of residents, building types, and climate zones will likely create a distribution of net benefits of energy savings.

Externalities from Energy Consumption

The broadest public benefit of reducing residential energy consumption is slowing climate change by reducing greenhouse gas emissions. Housing is a major consumer of energy, which has global implications, as the United States is the second largest energy consumer in the world. In the United States, 39 percent of energy use and 72 percent of electricity use originates from buildings, more than one-half of which is attributed to residential buildings (Im et al., 2017). Residential buildings contribute to between 20 and 25 percent of total greenhouse gas emissions (Im et al., 2017).

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[6] See https://web.archive.org/save/https://www.hud.gov/program_offices/housing/mfh/green. The ENERGY STAR benchmarking rates the energy use intensity (EUI) of the building compared to the predicted EUI of a building with similar characteristics. See https://web.archive.org/web/20220201055308/http://www.energystar.gov/sites/default/files/tools/Multifamily_August_2018_EN_508.pdf.

[7] Gillingham et al. (2018) conclude that most of the reduction in energy consumption appears to be driven by changes in natural gas rather than electricity. Their review includes Aroonruengsawat (2012), Jacobsen and Kotchen (2013), Kotchen (2017), Levinson (2016), Novan et al. (2017).

Residential Energy Use and Greenhouse Gas Emissions

About half of the energy used in homes is from space conditioning (heating and cooling). Electricity and natural gas are the two primary sources used by the majority of American households for space heating and cooling, water heating, and cooking (EIA, 2021; 2015 RECS[8]). Only a minority of electricity is currently produced through renewable sources. Thus, for most households, using more energy creates more pollutants and greenhouse gas emissions. These cause damaging and harmful economic externalities, including reduction of agricultural productivity, sea level rise and the accompanying cost of infrastructure for mitigation, adverse health effects, storms, and extreme weather events, and increased residential energy expenditures to maintain comfort (Auffhammer, 2018). Costs of greenhouse gas emissions that are not as easy to monetize include the loss of ecosystems and biodiversity.

Climate Change and Housing Affordability

The impact of climate change on the affordability of housing is expected to be adverse; thus, mitigating these effects is critical and aligns with HUD's mission. The frequency of billion-dollar disasters is steadily increasing. The US saw 20 separate billion-dollar weather and climate disasters in 2021, including winter storms, wildfire, drought and heat wave, floods, tornados, and tropical cyclones (Smith, 2022). Sea level rise and the accelerating number of natural disasters such as floods and wildfires are expected to destroy existing housing and reduce the supply of buildable land. The Union of Concerned Scientists projects that over 300,000 coastal homes, home to half a million people, will be at risk of chronic inundation by 2045 (Dahl et al., 2018).

Increasing risks due to weather-related events will increase the cost of property and flood insurance. Income taxes and property taxes will have to increase to pay for the infrastructure needed to mitigate risk.[9] These future economic costs are found to be priced into residential real estate by younger home shoppers (Baldauf et al., 2020).[10] Examination of mortgage markets finds that banks tighten private mortgage lending standards in disaster-hit counties, lowering access to mortgage credit (Duanmu et al., 2022). At the same time, lenders are more likely to approve mortgages that can be securitized, thus transferring credit risk to government-sponsored enterprises (Ouazad and Kahn, 2019).

Health Impacts

The social costs of greenhouse gases are widely dispersed. Energy inefficiency in housing contributes to negative externalities by requiring excessive energy production that has uneven and disproportionate health and safety impacts on poorer, more vulnerable populations with less capital to move away from energy production sites and power plants. A greater share of people of color and people below the poverty level live near coal- and oil-fired power plants, compared to the US population overall (Massetti et al., 2017). The American Lung Association has found that 150 million Americans are exposed to unhealthy levels of air pollution, much of which comes from power plants (American Lung Association, 2020). On top of the uneven spatial distribution of toxic releases, pollution-driven losses will not be distributed equally because the most vulnerable populations have a lower capacity to prepare for and adapt to the challenges introduced by climate change (Reidmiller et al., 2017). If lower-income communities are less resilient, then pursuing a cost-effective climate change policy could

[8] 2020 RECS data on fuels used and end uses were not yet released as of the date of this draft.

[9] The costs to local governments affect the long-run pricing of municipal bonds (Painter, 2020).

[10] There is, however, significant evidence in this study and others that financial markets do not always price the risk of climate change.

disproportionately benefit the poor. Preventative measures that protect the safety, health, and the land itself can be considered necessary for sustaining the economy. While each household's contribution to emissions is very small, any reduction to emissions can generate positive economic benefits in the future for all.

Investment in Energy Efficiency

Another argument for energy-efficiency policy is that there is an energy efficiency gap from an unmet demand for energy-efficient housing (Allcott and Greenstone, 2012; Gerarden et al., 2017). A minimum standard would be required to correct such a market failure. The economic benefit of a minimum efficiency standard would be the consumer surplus from greater comfort and lower energy costs. Potential factors behind an energy efficiency gap can be categorized into demand-side and supply-side failures. A demand side failure would arise if a consumer did not buy or rent energy-efficient housing even if they would gain from it. Explanations for demand-side failures typically rely on inattention, costs of search, and asymmetric information. Supply-side obstacles exist when there is unmet private demand for energy-efficient housing, if consumers are willing to buy but the real industry is unwilling to build. Potential supply failures could include lags in innovation, R&D, and elements of imperfect competition.[11]

Gerarden et al. (2017) indicate that apparent underinvestment could be explained by three factors: market failures such as principal-agent issues and asymmetric information, behavioral explanations such as "inattention to operating costs, myopia, and cognitive limitations"; and modeling flaws. A modeling flaw would arise from overstating the expected energy usage, understating the cost, not accounting for behavioral adaptations to the energy market, or the variance in distribution of benefits from adopting higher efficiency.[12]

In a perfect market, the demand for energy-efficient housing would be a sufficient incentive for supply. Homebuyers and renters would recognize the value of lower energy bills ex ante, bid for energy-efficient housing, and provide an incentive for developers to build efficient housing. If the housing market functioned perfectly, then any distortion would be at a net cost. Builders or consumers who had not already adopted an energy-efficient design would have refrained because there are no private benefits. Those who have adopted energy efficiency would not be affected by the Notice. [13] Thus, identifying potential market barriers is essential to understanding what portion of the estimated energy savings can be claimed as benefits.

Rational inattention is a compelling explanation for consumers ignoring energy efficiency (Sallee, 2014). Rational inattention can be expected to dominate in housing markets. As observed by Allcott and Greenstone (2012), the absolute value of energy costs is greater for housing than for any other consumer durable, but the relative cost (compared to the purchase price) is smallest. Thus, energy cost savings valued at $4,000 may not attract a buyers' attention when the mere transaction costs of a

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[11] Gerarden et al. (2017) find little evidence of these types of supply-side market failures.

[12] Failure to account for differences can lead to an overestimate of the net benefits. Those who adopted energy efficiency would have expected the NPV to be positive whereas those who haven't may be characterized by relatively low net benefits of adoption.

[13] Metcalf and Hassett (1999) do not find an extranormal return to residential energy investment for retrofits but rather a rate of profit, about 10 percent, closer to what one would earn from a typical risky investment. This would indicate that there is return to energy investment but not that there are market barriers.

mortgage loan are just as great. Other variations in the purchase or rental price due to its size, structure, or location may distract the potential tenant from weighing energy efficiency.

Asymmetric information exists when there is a significant barrier to one party in a transaction having all of the relevant information regardless of the search costs. Lack of transparency concerning energy efficiency would create a "lemons" problem. The seller has more information regarding the true value of a good than the buyer, which results in the buyer not wanting to pay more than the average price. This benefits the seller if the good is a "lemon" (defective) but is a disadvantage if the good is of high quality. The market for higher quality goods would collapse under such asymmetric information (Akerlof, 1970). Energy efficiency quality is not entirely asymmetric. Building inspectors can provide actionable information, if at a cost. Also, understanding the building code allows a potential tenant to make a guess concerning energy efficiency of new construction, but the energy efficiency of an existing home is also highly dependent on the evolution of building quality. There is not complete transparency either. Even if a buyer or renter were intent on shopping for the most energy-efficient home, it would be impossible to audit energy efficiency because there would be no previous utility bills for newly constructed housing. Energy efficiency tests like blower tests and infrared imaging are typically done at the time of construction and are not witnessed by customers shopping for newly constructed homes.

Standards provide a useful reference that have been verified by researchers and, even if not exact, provide an estimate of savings. Even so, there can be a level of uncertainty as to whether the code was followed correctly. One study (Giraudet et al., 2018) found that "energy savings are significantly lower when those measures were installed on a Friday—a day particularly prone to negative shocks on workers' productivity—than on any other weekday." Gerarden et al. (2017) point out that the prevalence of adverse selection is difficult to evaluate given that researchers would face the same information asymmetries as market participants.

Complicating the valuation of energy efficiency are other factors beyond the structure itself: uncertainty concerning the length of tenure, future energy prices, weather patterns, and other factors that could lead to more intensive energy use.[14] A consumer may eventually learn how to identify and value the benefits of energy efficiency, but the housing market inhibits frictionless adjustment through moving and other transaction costs in both the rental and owner-occupied market.[15] Thus, improving energy efficiency could be a benefit, especially for less informed renters and buyers (80 percent of FHA-insured households are first-time homebuyers) who may not have the market power to redirect the market towards beneficial investments.[16]

[14] Uncertainty concerning future trends is not a market failure but can exaggerate market failures when there is imperfect information concerning the effectiveness of the appropriate response (energy-efficient housing) to likely trends.

[15] It is also more expensive to retrofit a home for energy efficiency than it is to install energy-efficient features at construction. Renters are likely not able to make any changes to the structure. For owners, the mortgage loan is perhaps the cheapest way of financing energy efficiency. A retrofit could be financed through a real estate-secured loan but the rate on HELOC's is generally higher than the original mortgage.

[16] Frondel et al. (2020) uncover implicit evidence that the choice of housing may be driven by actual preferences for energy efficiency rather than any ignorance.

Builders, sellers, and landlords will be inhibited from providing energy efficiency if buyers and renters do not exhibit a clear pre-purchase preference for energy efficiency.[17] The longer the housing remains empty, the greater the costs to the developer or owner. The same is true of an owner-occupant, who by purchasing housing becomes a supplier of housing services. The owner, even if they value energy efficiency in their own housing, may be hesitant to invest in energy-efficient features if they doubt that they can sell the home for at least as much as they paid. The difficulty for the supplier is in matching the buyer. All of the search costs reduce the probability of matching and increase the opportunity costs of building a product that deviates from the average. And it appears that shoppers' tastes are heterogeneous. For example, Fischbacher et al. (2021) find that households measured to be less risk averse and with lower discount rates are more likely to engage in energy-efficient retrofits. Augmenting minimum standards for new construction would expand choice for buyers in the market for energy-efficient housing but, because most of the housing stock is already built, would not impose significant costs on those who do not desire energy efficiency.

Giraudet (2020) concludes that asymmetric information in rental housing is the most compelling example of an energy efficiency gap in the housing market. Cellini (2021) and Gillingham et al. (2012) find that owner-occupied units are more likely to have structural energy saving measures such as insulation. Myers (2020) finds that landlords underinvest in energy efficiency, passing along costs of approximately 24 percent of heating fuel costs. Petrov and Ryan (2021) find that renters pay significantly higher energy bills than owners, especially in tight housing markets. Souza (2018) finds less investment in energy efficiency among renters. The difference declines for longer term renters, suggesting diminishing asymmetric information. The split-incentive issue extends to all energy consumption: Davis (2011) finds that renters are also less likely to have energy-efficient appliances.[18] Renters also face unique problems depending upon how landlords charge for utilities. If utility costs are paid by the landlord who then passes them onto the tenant as part of the rent, then tenants may not be as aware as to how their own behavior affects energy costs. Also, if landlords practice average cost pricing, then the incentive for energy conservation by renters is completely removed. Brewer (2020) finds that renters paying their own heating bill consume 25 percent less energy. Mandating energy efficiency is not necessarily the optimal response but will reduce excess energy consumption if there are market failures stemming from principal-agent problems.

Evidence of an energy efficiency gap can be estimated through several approaches: engineering estimates of returns to potential investments, empirical estimates of returns to observe, cost-effectiveness of energy estimates of returns to observed investments, cost-effectiveness of energy conservation programs run by electric utilities, and estimated demand for energy-using consumer durables (Allcott and Greenstone, 2012). There are, unfortunately, no ready-to-use measures of the energy efficiency gap for this regulatory impact analysis. Technical estimates suggest that there are significant gains to be had. An economic tautology would suggest that if an energy-efficient investment is not undertaken, then it is because there is an expected loss. The bulk of evidence indicates that the expected result is somewhere in between. There do appear to be empirically measured inefficiencies,

[17] A study of fuel efficiency (Gillingham et al., 2021) in automobiles finds consumer myopia: that buyers are willing to pay only a fraction in higher prices for future savings ($.16 to $0.39 higher price in exchange for a present value of $1.00 discounted fuel savings). Estimates of consumer behavior in the used car industry, supports that there is a minor undervaluation of energy efficiency (Allcot and Wozny, 2014).

[18] This could also be explained by a rental externality in which renters may spend less maintaining their housing.

especially for rental housing. There are aspects of the housing market infused with information problems that could inhibit the valuation of energy efficiency. Still, determining the size of the energy efficiency gap is a challenge. Given the diversity of climate zones, housing markets, residents, and tenure types, any average will be misleading. The divergence between an ex-ante technical estimate and ex post economic estimate will depend on the accuracy of the estimate, the design being evaluated, and historic trends since the implementation of an energy efficiency policy.[19] The best that we can do is recognize that there can be a difference between predictions and eventual outcomes.

Lacking a parameterization of unrealized energy savings, our approach is to model the benefits of improved energy efficiency in a way that aligns the technical estimates with the economics of asymmetric information in the housing market. HUD assumes three levels of energy saving benefits, from the most limited to the most inclusive.

In our lower estimate, only publicly funded or managed housing is assumed to gain. This lower estimate includes housing that HUD determined would gain. As long as the NPV of the project is positive, then the net outcome for tenants will be to reduce their housing costs (rent plus utilities). Private owners are assumed to neither gain nor lose in this scenario.[20]

Our intermediate scenario is characterized by an energy efficiency gap in rental housing. Empirical work has uncovered that, relative to owner-occupied housing, rental housing is less energy-efficient. As long as the NPV of the energy efficiency standards are positive, we assume that there will be a gain shared by the landlord and renter. This intermediate case also includes publicly managed homes.

The largest estimate includes owner-occupants, who were excluded from the low and middle estimates because owners have the most direct incentives to purchase efficiently. Nonetheless, it is possible that energy efficiency gaps exist, especially for first-time homebuyers.

[19] The design of the standard is crucial. Some energy standards may produce net benefits while others will not. For example, Fowlie et al. (2018) found that although weatherization was expected to produce net benefits, a retrospective analysis found a negative return (-7.8 percent). (This is partially due to a high upfront cost of investment ($5,150), which included both energy efficiency investments and additional house improvements needed to ensure a safe working environment.) On the other hand, Novan et al. (2017) finds that, over a 30-year time span, minimum energy standards for residential buildings are effective and yield positive returns.

[20] Most estimates of the NPV are positive. There may be additional opportunity costs, but we assume those opportunity costs are paid for the by the gains.

Figure 3. Failures in Energy Efficiency Investment

Source of Inefficiency	Description	Programs Affected
Government	Lack of private incentives leads to underinvestment in energy efficiency	PIH, HOME, Housing Trust Fund
Landlord-Tenant	Principal Agent problems between tenant and landlord leads to undersupply of energy efficiency in rental housing	FHA Multifamily
Builder-Homebuyer	Rational ignorance or asymmetric information leads to homebuyers forgoing energy efficiency	FHA Single Family, Condos, USDA Guaranteed Loan Program, USDA Direct Loan Program

Long-term Viability of HUD-Assisted Property

HUD has a direct financial stake in the energy efficiency of many of the multifamily properties affected by this Notice– i.e., those FHA-insured and other multifamily properties for which HUD subsidizes utility costs through operating subsidies or Section 8 rental assistance. This is in contrast to other programs, such as FHA single-family insurance, where the upfront costs of the minimum energy standard could be viewed as a burden to some private actors. Instead, for programs such as the Public Housing Capital Fund, updating energy efficiency standards will likely reduce the costs to the government provision of housing services. Evidence from engineering studies suggests that adopting IECC and ASHRAE for multifamily properties will allow HUD to provide more housing units by lowering joint housing and energy costs.

This Notice affects three categories of housing financed or assisted by HUD and USDA: (1) new construction of public and assisted single-family and multifamily housing with mortgages insured by HUD; (2) new construction of single-family housing with mortgages insured or guaranteed by USDA; and (3) new construction of public housing.[21] This Notice also applies to new construction of rental and homeownership housing assisted under the HOME Partnership Grants Program.[22] Of the affected programs, the Public Housing Capital Fund, Capital Fund Financing Program, and Choice Neighborhoods Implementation Grants are the most likely to affect government costs.

Energy Independence and Security Act of 2007

The Energy Independence and Security Act of 2007 mandates that HUD and USDA apply the revised standards of IECC or ASHRAE 90.1 to the relevant public or assisted program. Implementing these standards is required by law. The HUD-USDA adoption of the updated standards is not a discretionary policy action. The Act does not require a discussion of market failures to justify updating the standards. Instead, the justification provided by the Act is:

"To move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products,

[21] HOPE VI is no longer funded so is not included in the Notice.
[22] The full list of affected programs is included in Table 1 of the Notice.

buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes."

HUD's only role is to "make a determination that the revised codes do not negatively affect the availability or affordability of new construction of assisted housing and single family and multifamily residential housing (other than manufactured homes)." However, evidence of market imperfections is critical to HUD's determination. Imposing minimum efficiency standards would diminish affordability and availability in the absence of market barriers.

Data

Estimate of Units Affected by Notice

Figure A1 in Appendix A provides the estimates of newly constructed housing units that would potentially be affected annually per state and territory by the 2021 IECC standards. These affected housing units include new single-family housing built with HUD and USDA assistance and new HUD-assisted or FHA-insured low-rise multifamily housing.[23] Using a 3-year annual average (2019-2021), before adjusting for existing state-level codes, there would be an estimated 170,000 housing units of HUD- and USDA-financed or -insured housing that may be impacted by the new energy standards. Of these, single-family homes (86 percent) represent most of the potentially affected units, while low-rise multifamily units are the minority (14 percent). Of the total, about 155,000 housing units (91 percent) are from HUD programs while approximately 15,000 units (9 percent) are from USDA programs. Geographically, 55 percent of the potentially affected housing units are concentrated in 5 states—Texas (24 percent), Florida (14 percent), Georgia (6 percent), North Carolina (5 percent), and California (5 percent)—while the rest are scattered around the country, with a share of 3 percent or less per state. When adjusted to exclude units in states that have already adopted codes equivalent to the 2021 IECC, the total potential number of units affected drops to around 160,000.

IECC single family

Among the newly constructed single-family housing units, 88 percent of the total units are from HUD programs while 12 percent are from USDA programs. Among the housing units from USDA programs, 86 percent are from the Guaranteed Loan Program while the remaining 14 percent are from the Direct Loan Program. On a state level, data show that the top five states represent 55 percent of the affected housing units—Texas (24 percent), Florida (15 percent), Georgia and California (6 percent each), and North Carolina (5 percent).

IECC multifamily

EISA does not cover USDA guaranteed multifamily housing. Accordingly, all low-rise multifamily units, making up 14 percent of the units affected by the IECC, belong to HUD programs, with 90 percent from FHA New Construction and HFA Risk Sharing, and 10 percent from FHA Single Family for condominiums. By geographical concentration, the top five states captured 52 percent of the total affected low-rise multifamily units—Florida (30 percent), New York and North Carolina (6 percent each), and Virginia (5

[23] Newly constructed housing units are from the HUD Programs—FHA Single Family, Public Indian Housing (Choice Neighborhoods, HOPE VI, Low Income Rental, Low Income/Fair Market Rent, and Mixed Finance), HOME, Housing Trust Fund, and Multifamily (FHA NC/SR Apartments and HFA Risk Sharing); and USDA Section 502 Programs—Guaranteed Loan and Direct Loan Programs.

percent). USDA guaranteed multifamily housing is not covered by EISA. Furthermore, we will assume that, because of the low density of rural areas, none of the USDA single-family housing are condominium units.

ASHRAE multifamily

Figure A2 in Appendix A provides the estimated number of newly constructed mid-rise or high-rise multifamily units that would be affected annually per state by the new ASHRAE-90.1 2019 standard. Using a three-year average, prior to adjusting for existing state-level codes, there are approximately 17,000 new mid- or high-rise multifamily units affected annually, comprised of 79 percent FHA-insured multifamily units, 16 percent HOME-financed units, 3 percent PIH-financed units, and 2 percent HTF-financed units. By state, the top five states constitute 49 percent of the total new mid- or high-rise multifamily units—Texas (26 percent), Florida (7 percent), New York (6 percent), North Carolina (5 percent) and Virginia (4 percent).

Analysis of Update to 2021 IECC

Single-family housing and low-rise multifamily housing up to three stories are covered by the IECC. Among all households, those in single-family detached homes use the most energy, followed by those in single-family attached homes, households in two- to four-unit buildings, and finally, households in large multifamily buildings (Obrinsky and Walter, 2016).

We start with an evaluation of the private impact of energy-efficient building codes.[24] There will be an upfront incremental cost of construction followed by a stream of benefits in the form of reduced energy bills. PNNL provides estimates of the incremental cost of construction and the annual reduction in energy savings. HUD uses the PNNL estimates to develop measures of the net present value of the energy-efficient investment. Following OIRA guidance, the NPV of the investment is HUD's primary estimate of the value of the policy change.

PNNL provides three other economic measures of the change in IECC requirements. The first is the simple payback measure, which is a measure of profitability. The two others, the cash flow analysis, and the life cycle cost measure, are measures of affordability for homeowners. HUD describes how these two measures of affordability may be different for FHA-insured borrowers.

Gerarden et al. (2017) warn against interpreting ex ante (pre-construction) estimates of energy savings as accurate measures of the gains to be had.[25] Generally, but not always, the researchers find that the ex post (post-construction) evaluations estimate a lower level of savings.[26] Gillingham et al. (2018) in their review of energy consumption and building codes find that more recent engineering predictions match fairly closely with ex post evaluations. A study (Chuang et al. 2021) of residential energy efficiency rebate programs estimates a realization rate of 65 percent for HVAC, 7 percent for lighting,

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[24] We use the term "energy-efficient" to describe any investment that allows resident to consume less energy and maintain the same level of comfort, referred to as "technical efficiency." We use the word "optimal" to describe economic efficiency as the action that maximizes net benefits, both private and public. See Saunders et al. (2021) for a discussion of different definitions of "efficiency."

[25] This finding does not imply that the engineering estimates were incorrect. Human behavior and unexpected changes in the energy market could affect the outcome.

[26] These authors also indicate that independent researchers may be biased and choose to evaluate programs with very large estimates of benefits.

and 19 percent for whole house retrofits. Novan et al. (2017) find that the ex ante engineering predictions for a California building code were accurate. We will use the PNNL estimates as a base because there is great variation by building type and climate zone and because the RIA is a predictive analysis.

We address the concerns that ex ante estimates are not always good predictors of economic gains by assuming different scenarios concerning the level of private energy savings depending on the economic agent's proximity to the energy efficiency investment decision. Our lowest estimate includes publicly managed properties only. In this scenario, we assume that the private benefits for participants do not outweigh the costs. In other words, that the marginal benefits of the energy efficiency upgrade are exactly equal to the marginal cost (as calculated by PNNL). The second level estimate includes all rental housing units. The third adds owner occupants.

Description of IECC Code Changes

The IECC has mandatory components and prescriptive components, which are required but can be lessened or eliminated in trade for compensating improvements elsewhere.[27] Some prescriptive components have backstops, or hard limits beyond which a prescriptive requirement cannot be traded any further.

The focus of the IECC is on the building envelope, which includes ceilings, walls, windows, floors, and foundations. The code sets insulation and fenestration levels and solar heat gain coefficients. It sets testing requirements, and caulking and sealing requirements for insulation control (to prevent air leaks) for ducts, air handlers, filter boxes, etc. The IECC also covers lighting requirements. It does not cover appliances and has limited space heating, air conditioning, and water heating requirements, which are typically not set by I-codes.

Between the 2009 and 2021 IECC, changes have included, among others: increases to how well a window insulates; increased thickness for water heating pipe insulation; inclusion of additional spaces subject to insulation requirements, such as sunrooms, combustion closets, and heated slabs; increases in the share of permanent light fixtures that must use high-efficiency lamps; and requirements for occupant sensor control lighting.

Net Present Value of the IECC Energy Code Change

The net present value of energy-related costs to the resident of a home can be described as the discounted sum of all energy bills over the planning horizon plus the upfront cost of building the structure to a specific level of efficiency. A recommended design strategy that lowers the NPV of costs would create economic surplus through an advantageous trade-off between construction costs and energy bills. A more stringent energy code can be expected to lead to lower energy expenditures at every time period, from the first year of the investment until the end of the planning horizon. Periodic energy expenditures, typically in the form of monthly utility bill payments, will vary by the climate zone, structural characteristics of the unit, size of the unit, local utility prices and fuel prices, and even the number and type of residents. For this analysis, future energy bills are discounted at rate ρ to derive a present value.[28]

[27] See https://www.energycodes.gov/sites/default/files/2019-09/2018_IECC_residential.pdf.

[28] See the Appendix concerning the calculation of the NPV for precise definitions of these expressions.

The cost of reducing future energy bills is the cost of purchasing and installing energy saving capital, realized at the time of construction.[29] The design standard is prescribed by the IECC and so the cost of construction will vary with the specific code. The IECC is given by the year of issuance on a three-year publication cycle: 2012, 2015, 2018, 2021. The cost of complying with a specific code will vary with a range of other variables. The climate zone-specific IECC requirement is a primary factor affecting the cost of compliance because the stringency varies by climate zone. Energy codes are more stringent in areas that face the most extreme and variable weather. Other factors affecting costs are the type and size of structure, price of materials, and local wages for construction workers.

The NPV of the change in energy standards is given by the change in energy expenditures as a result of the change in standards and the change in construction cost. The impact of the requirement will depend upon existing state requirements. Because of HUD and USDA's prior Notice implementing the 2009 IECC, the most common incremental change likely to be experienced is from IECC 2009 to IECC 2021. Other states have adopted higher standards than the 2009 IECC. The second most common is from IECC 2018 to IECC 2021. A breakeven condition for the design standard for an individual structure i would be given by the present value of energy savings exceeding the incremental cost of construction.

PNNL estimates that the average national energy costs per year for the 2018 IECC are $2,139, dropping to $1,954 for the 2021 IECC. This reflects national average site energy use intensity of 36.4 kBtu/ft^2-yr for the 2018 IECC dropping to 33.0 kBtu/ft^2-yr for the 2021 IECC. Multifamily units are expected to see a greater percent energy savings than single-family units.

Figure 4 shows the average national energy cost savings estimated with each version of the IECC. The greatest incremental savings come from the 2012 IECC, followed by the 2009 IECC, followed by the 2021 IECC. PNNL provided HUD with cost and benefit estimates for adopting the 2021 IECC from a baseline of the 2009 IECC, and has made publicly available estimates for adopting the 2021 IECC from a 2018 IECC baseline. For states that have adopted standards equivalent to the 2012 or 2015 IECC, HUD uses the estimates for the adoption from the 2018 to the 2021 IECC, as the 2012 and 2015 IECC both are closer to the 2018 IECC than the 2009 IECC.

Most states are also adopting standards on their own as they are updated. Many jurisdictions adopt codes on three- or six-year cycles, and some have provisions allowing for modifications to be considered on an annual or biannual basis (ACI, 2020). To this extent, the costs of complying with the Notice will fall as some states adopt the same 2021 IECC and 2019 ASHRAE 90.1 standards on their own; currently, a limited number of states have adopted these standards.

Figure 4. Incremental Energy Savings Associated with Each IECC Version 2006 to 2021

Year of code	Comparison year	National weighted energy cost savings (%)
2009	2006	10.8
2012	2009	23.9
2015	2012	0.7
2018	2015	2.0
2021	2018	8.7

[29] There may be other costs such as periodic maintenance or economic opportunity costs, which are discussed in a separate section of the RIA.

Sources: 2012: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22068.pdf;
2015: https://www.energycodes.gov/sites/default/files/2021-07/2015_IECC_FinalDeterminationAnalysis.pdf;
2018: https://www.energycodes.gov/sites/default/files/2021-07/EERE-2018-BT-DET-0014-0008.pdf,
2021: https://www.regulations.gov/document/EERE-2021-BT-DET-0010-0006

HUD bases its analysis of NPV on the cost-effectiveness studies by PNNL. The key estimates used are first-year energy savings and incremental construction costs of different changes in the IECC for different types of homes. The estimates are national averages across climate zones and foundation type. The square footage is held constant for all estimates of the single-family home (approximately 2400 square feet) and multi-family homes (1200 square feet).

Figure 5. Incremental Effects of IECC Updates (Per Unit)

Housing Type	2009 IECC to 2021 IECC			2018 IECC to 2021 IECC		
	Incremental Construction Costs ($)	First Year Energy Savings ($)	Simple Payback (years)	Incremental Construction Costs ($)	First Year Energy Savings ($)	Simple Payback (years)
Single-family	5,555	752	7.4	2,372	210	11.3
Multifamily	2,307	315	7.3	1,316	154	8.5

*Source: The averages for incremental costs and energy savings for the 2009 to 2021 change were provided to HUD by PNNL. The costs for the 2018 to 2021 change are from Table 11 of the IECC National Energy Effectiveness Report (Salcido et al., June 2021). The report does not provide first-year energy savings for single-family and multi-family separately, but a national average ($191 from Table 13 of Salcido et al., June 2021). HUD derived the energy savings for single-family and multi-family by combining estimates from PNNL's IECC 2021 Energy Savings report (Salcido et al., July 2021), which provides separate estimates for single-family and multi-family energy first year savings ($204 and $150, respectively, calculated from Tables ES.5 and ES.6). Applying PNNL's unit-type weights of 33.96 percent for multi-family and 66.04 percent for single-family yields an average of $186. To make the construction cost and energy savings consistent, HUD adjusted the energy savings figure by approximately 3 percent ($191 average savings from the June 2021 PNNL report divided by HUD-calculated $186 average from the July 2021 PNNL report).

A few things are clear from the PNNL engineering estimates of incremental costs and first-year energy savings. Although the upfront costs of shifting from the 2009 code are much greater than from the 2018 code, the relative energy savings realized are more favorable, as shown by the lower simple payback period. Costs and energy savings are greater for larger single-family homes than for smaller multi-family homes. For the change from 2009 to 2021, the simple payback is similar for multifamily and single-family. For the change from 2018, the single-family savings are relatively less favorable, as indicated by a higher payback period. The simple payback, the ratio of incremental costs to incremental savings in the first year (which approximates the average annual savings), serves as a rough measure of the return from the investment. Simple payback is an intuitive approximation of the number of years required for the stream of benefits to exceed the upfront cost.[30]

To determine whether the incremental change is cost-effective, HUD compares the present value of energy savings over the lifetime of the investment with the initial cost. The present value of the stream of future energy savings is derived from the first-year energy savings and the present value multiplier. The present value multiplier depends on the discount rate, energy price growth rates, and lifetime of

[30] The simple payback period is equivalent to the break-even lifetime of a project in the absence of discounting or trends in real energy prices. Adding dynamics complicates the analysis but is necessary for a more accurate estimate of the value of the energy-saving investment.

the investment. The stream of benefits is assumed to begin immediately upon investment. The present value multiplier increases with energy price growth and the lifetime of the investment and decreases with the discount rate. Because later years are discounted more heavily, there are diminishing returns to a longer lifecycle.

Figure 6. Present Value Multipliers

Lifetime (years)	No real energy price growth		Annual real energy price increase of 1%		Annual real energy price decline of 1%	
	Discount Rate		Discount Rate		Discount Rate	
	3%	7%	3%	7%	3%	7%
20	15.3	11.3	16.7	12.2	14.1	10.5
25	17.9	12.5	20.0	13.6	16.2	11.5
30	20.2	13.3	22.9	14.7	17.9	12.1
40	23.8	14.3	28.0	16.1	20.5	12.8

Presenting a range of 18 different present value multipliers allows the reader to choose which one is appropriate and to conduct their own sensitivity analyses using PNNL estimates. Comparing the simple payback period calculated by PNNL with the present value multiplier indicates the robustness of the breakeven criterion for the energy-efficient investment.[31] With discounting and price trends, the PV multiplier must be greater than the simple payback period, t^*, for the investment to reduce total energy-related costs.

$$PV > t^*$$

If the simple payback ratio in Figure 5 is less than the present values multipliers for a scenario in Table B, then the net present value of the project is positive for that scenario.[32]

As shown in Figure 5, the simple payback of the 2009 to 2021 update is 7.4 years for the average single-family home, and 7.3 years for PNNL's multifamily unit. Comparing the simple payback of 7.4 and 7.3 to the values in Figure 6, the average investment would result in a surplus, even for the least favorable scenarios considered. The 2018 to 2021 update change would yield positive results for the average multifamily housing in all scenarios. The 2018 to 2021 for single family homes would be positive for most scenarios except for two of the least favorable: a 7 percent discount rate, short lifespan, and no positive energy price growth.

The absolute value of the IECC update is shown for a base case of 0 percent real price growth and a lifetime of 30 years at two different discount rates. The PV multiplier is 20.2 for the 3 percent discount rate and 13.3 for the 7 percent discount rate. The net present value of the investment is given by the present value of the first-year energy savings less the incremental construction cost. Some researchers have stressed the importance of discount rates. Estimates of discount rates on energy-saving appliances

[31] As described by PNNL in its evaluation of the cost effectiveness of the ANSI/ASHRAE 90.1-2019 standard, the simple payback is not a formal measure of cost effectiveness, but reported for informational purposes only https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29940.pdf .

[32] NPV is positive if PV x E > C, where PV is the present value multiplier, E is the value of the incremental energy savings, and C is the incremental cost of the energy standard.

range from 10 to 25 percent, with significant heterogeneity across individuals and households (Hausman 1979, Dubin and McFadden, 1984, Newell and Siikamäki 2015).

Figure 7. Per Dwelling Unit NPV of IECC Updates from 2009 and 2018
(For zero real price growth and 30-year lifetime)

	2009 to 2021 IECC Update			2018 to 2021 IECC Update		
Housing Type	**Incremental Construction Cost ($)**	**PV of Energy Savings ($)**	**Net Benefit ($)**	**Incremental Construction Cost ($)**	**PV of Energy Savings ($)**	**Net Benefit ($)**
	3% discount rate					
Single-family	5,555	15,182	9,627	2,372	4,240	1,868
Multifamily	2,307	6,359	4,052	1,316	3,109	1,793
	7% discount rate					
Single-family	5,555	9,985	4,430	2,372	2,788	416
Multifamily	2,307	4,182	1,875	1,316	2,045	729

Present Value Multiplier Assumptions

The assumptions behind the present value multiplier are of critical importance to the estimate of the net present value of the code update.

Energy price growth is the annual rate of residential price changes, accounting for inflation. The predicted change varies by energy source. Currently, most residential energy consumption is for space and water heating. Natural gas is the major source for both, followed by the purchase of electricity. The National Institute of Standards and Technology provides estimates for fuel price escalation.

Figure 8. Estimates of Real Energy Price Growth (% change)

	Compounded Rate 2021 to 2026	Annual Rate 2021 to 2026	Compounded Rate 2026 to 2031	Annual Rate 2026 to 2031
Electricity	0.0	0.00	0.1	0.0
Distilled Oil	5.6	1.10	1.4	0.3
Liquefied Petroleum Gas	2.3	0.46	2.2	0.4
Natural Gas	-0.2	-0.04	1.5	0.3

Source: Table Cb-5, Energy Price Indices and Discount Factors for Lifecycle Analysis 2021, April 2021.

From these projections, a 0 percent change would be a reasonable estimate. Estimates by the Energy Information Administration from their 2022 Annual Energy Outlook project very little change in electricity prices over the coming decades (on average -0.3 percentage points annually over the next thirty years). However, energy prices are difficult to predict. Energy prices tend to be more volatile than other commodities, due partly to the inability of consumers to substitute quickly to alternative sources. Within the last 12 months since March 2022, the (seasonally unadjusted) nominal change in energy prices was 11.1 percent for electricity, 13.5 percent for natural gas, and 70.1 percent for fuel oil. These nominal changes in energy prices compare with a 5.0 percent increase in shelter. Aggregate changes in the last year include all items at 8.5 percent, commodities less food and energy at 11.7 percent, and services less energy services at 4.7 percent.[33] These more recent trends suggest that choosing the scenario of increasing prices would be reasonable if current trends continue.

The lifetime of the investment was assumed to be thirty years. PNNL uses 30 years as the effective life in their analysis for IECC. PNNL models critical repairs or replacement in their lifecycle cost analysis. Unfortunately, these technical parameters are not available from the PNNL report on which much of HUD's analysis is based. Alternative approaches to modeling deterioration would be including an annual average depreciation rate for energy-efficient investment. Another approach, adopted implicitly in this analysis, would be to assume full capacity for the lifetime of the system, which terminates after a given year. The difficulty in either of these approaches is that the IECC energy efficiency prescriptions pertain to different systems: lighting, windows, air seals, ceiling and wall insulation, the type of wall frame, insulation of the slab, and options related to air and water heating. Some of these changes, such as ceiling and wall insultation, can be expected to last for the lifetime of the structure, at least 40 years. Others, such as windows and water heaters, would experience a shorter effective life span, closer to 20 years. In its analysis of ASHRAE 90.1 – 2019 standards of mid-rise apartment buildings, PNNL assumed a lifetime of 40 years for insulation and a replacement cycle of 15 years for HVAC.

In practice, the lifespan of any of these components will vary by factors including initial quality, maintenance, and unexpected damage. Bourland (2009) uses an average lifespan of 25 years for structural components of buildings encouraging efficient energy use. Often, researchers assume longer project lifetimes such as 30 or 40 years for efficient energy use in residential buildings. These longer terms more closely match the typical mortgage loan (30 years) or the useful life of a residential building under the alternative depreciation system (40 years). An average of 20 years would be a modest estimate of the lifespan of the improvements; 25 years would be slightly more expansive but credible; and 30 years would be a slightly generous estimate. Novan et al. (2017) use 30 years as the time horizon for their study of the impacts of an energy code implemented in 1978. The NPV of the lifespan of the shorter lifespan of 25 years remains favorable for the 2009 to 2021 update.

Discount rates of 3 percent and 7 percent are recommended by OIRA. The 7 percent discount rate represents the real pre-tax return to capital. The 3 percent discount rate approximates the rate at which society as a whole discounts future consumption and is derived from the real interest rate on Treasury bonds. There are other reasons that future energy savings may be discounted compared to present ones. The purchaser may be unsure about whether these future savings will be realized for a number of reasons, including unexpected costs of repair, energy price volatility, expected length of tenure, and valuation by a future buyer.

IECC Internal Rate of Return

The internal rate of return (IRR) is a financial measure of the profitability of an investment that yields benefits and costs over an extended time period. Defined as the discount rate that would yield a NPV of zero, calculating the IRR of the updates to the standards is helpful as a means of checking the economic reasonableness of an investment. A discount rate lower than the IRR would yield a positive NPV; a discount rate higher than the IRR would yield a negative NPV. The IRR is used in real estate as a metric to compare with opportunity costs of capital, such as the cost of debt. Knowing the IRR provides another

[33] BLS Consumer Price Index March 2022 New Release, April 12, 2022.

perspective than the NPV.[34] An IRR below what can be earned through other investments is the opportunity cost of capital. Likewise, an abnormally high IRR could imply that the reward is exaggerated.[35] A higher rate of return indicates a project with greater present value in-flows relative to the present value of out-flows over the lifetime of the project.

Figure 9. Per Dwelling Internal Rate of Return (%) of IECC Updates from 2009 and 2018 (For zero real price growth and 30-year lifetime)

Housing Type	2009 to 2021 IECC Update	2018 to 2021 IECC Update
Single-family	15.4	8.9
Multifamily	15.6	12.9

There are no hard and fast rules for what constitutes a good IRR, except that it should at least exceed the opportunity cost of capital.

Adjusting for Size of Home

The cost of compliance with the energy code and resulting gains in energy savings will vary with the size and type of structure. A larger home is generally more expensive to build and consumes more energy. The structures purchased and rented through HUD and USDA programs are, on average, smaller than the model homes used by PNNL, so the energy savings and the costs of building to the energy code are expected to be lower. The average single-family home insured by FHA is approximately 2,000 square feet, whereas the model home analyzed by PNNL is almost 2,400 feet. HUD does not expect that the reduction in costs and benefits will be exactly proportional to the change in square footage (an approximate 17 percent decline). Because there are some aspects of energy-efficient construction and consumption that do not vary with the size of the home, the reduction to the cost of compliance and to the benefits is somewhat less than the reduction of areas (less than 17 percent). There is no reason, however, that the benefits and costs should vary at the same rate. This is evident from the diversity of simple paybacks. How they vary could affect whether there is any economic surplus (net cost savings) for projects near the breakeven point.

HUD investigates how the benefits and costs could vary in Appendix B. We find it reasonable to project that energy savings would fall by approximately 5 percent while construction costs could fall by 10 percent, to account for smaller sized FHA or USDA-financed homes. At the same time, given the tremendous diversity of structure types and climate zones, it is perhaps best to simply recognize that size difference introduces some inaccuracy to our estimates based on the model homes used in PNNL's analysis. For example, if costs fall by 10 percent and benefits by 5 percent, there is an additional margin for the project to break even. The reverse would be true if costs were to fall by 5 percent and benefits by 10 percent.

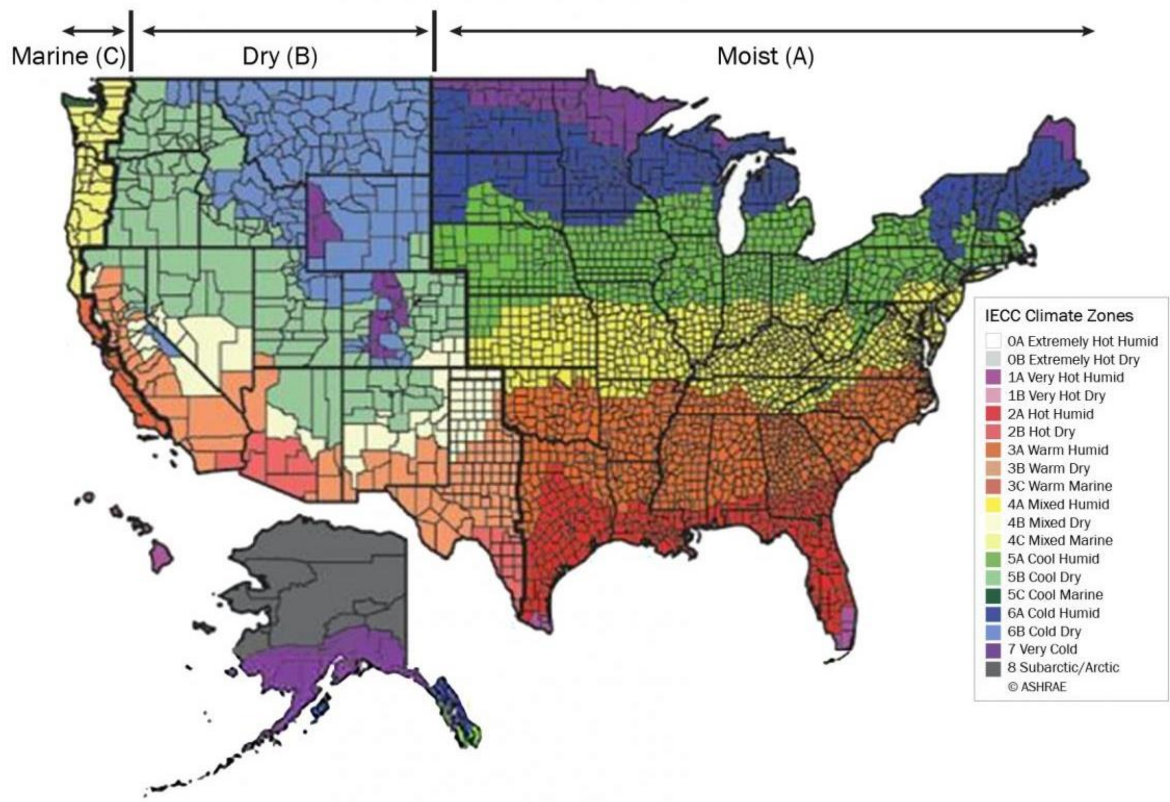
[34] IRR is not the same as the return on investment (ROI) but instead is better complement to the NPV approach used throughout this analysis.

[35] An extremely high IRR is not evidence of incorrect technical estimates but serves as a check. Industry standards suggest that IRRs vary between 10 and 20 percent. The level of risk and debt-finance would increase the required IRR.

Variation by Climate Zone

The center of our analysis is the national average, but it is worth exploring differences by climate zone. The IECC recommendations vary substantially by climate zone to promote the cost-effectiveness of the code. Generally, the relationship between costs and energy savings follows a pattern: climate zones with higher costs also experience higher benefits. There are exceptions. Standards for Climate Zone 5 impose the second highest average upfront costs of all eight climate zones but offers the second lowest benefits. The simple payback varies by climate zone around the national average of 7.4 for single-family and 7.3 for multifamily. Climate Zone 8 has the most favorable simple payback and Climate Zone 2 has the least favorable simple payback for the change from 2009 to 2021. The NPV of the 2009 to 2021 update is positive even for the least favorable scenario of a short time horizon (20 years), high discount rate (7 percent), and energy price decline (-1 percent).in all climate zones.

Figure 10. IECC 2021 Climate Zones



Source: https://basc.pnnl.gov/images/climate-zone-map-iecc-2021

Figure 11. IECC Update 2009 to 2021: PNNL model homes

Single-Family Units			
Climate Zone	**PNNL Incremental Cost ($)**	**PNNL Annual Energy Savings ($)**	**Simple Payback (Years)**
National Average	5,555	752	7.4
Climate Zone 1: Very Hot	2,813	475	5.9
Climate Zone 2: Hot	4,177	475	8.8
Climate Zone 3: Warm	6,175	751	8.2
Climate Zone 4: Mixed	6,618	956	6.9
Climate Zone 5: Cool	5,955	852	7.0
Climate Zone 6: Cold	5,291	1,179	4.5
Climate Zone 7: Very Cold	6,794	1,544	4.4
Climate Zone 8: Subarctic/Arctic	6,796	1,926	3.5
Low-rise Multifamily Units			
Climate Zone	**Incremental Cost ($)**	**Annual Energy Savings ($)**	**Simple Payback Period (Years)**
National Average	2,307	315	7.3
Climate Zone 1: Very Hot	1,686	280	6.0
Climate Zone 2: Hot	2,139	272	7.9
Climate Zone 3: Warm	2,473	313	7.9
Climate Zone 4: Mixed	2,372	339	7.0
Climate Zone 5: Cool	2,310	307	7.5
Climate Zone 6: Cold	2,147	408	5.3
Climate Zone 7: Very Cold	3,647	592	6.2
Climate Zone 8: Subarctic/Arctic	3,646	742	4.9

Source: Estimates provided to HUD by PNNL

For the change from 2018 to 2021, HUD does not have the PNNL estimates of energy savings disaggregated by single-family and multifamily for their national averages. Instead, the report presents separate estimates of the incremental cost and an average level of first-year energy savings for multifamily and single-family units. To compare the upfront costs and future benefits by climate zone, HUD computes a weighted average of the incremental cost of construction. The weights used by PNNL in their analysis are 66 percent for single-family units and 34 percent for low-rise multifamily units. HUD uses PNNL weights to calculate the average cost so that the cost estimates are consistent with PNNL's weighted average annual first-year energy savings. Table 12 shows the energy savings and incremental costs of construction for the average housing unit (average of single family and multifamily).

Figure 12. Incremental Costs and Energy Savings of IECC 2018 to IECC 2021

Area	Upfront Cost for Single-Family ($)	Upfront Cost for Condo ($)	Upfront Cost for Average Unit ($)	First Year Energy Savings for Average Unit ($)	Simple Payback for Average Unit (years)
National Average	2,372	1,316	2,013	191	10.5
Climate Zone 1: Very Hot	936	933	935	200	4.7
Climate Zone 2: Hot	1,530	1,146	1,400	192	7.3
Climate Zone 3: Warm	1,859	1,192	1,632	200	8.2
Climate Zone 4: Mixed	3,687	1,533	2,956	205	14.4
Climate Zone 5: Cool	3,569	1,487	2,862	173	16.5
Climate Zone 6: Cold	1,477	1,102	1,350	123	11.0
Climate Zone 7: Very Cold	2,980	2,603	2,852	306	9.3
Climate Zone 8: Subarctic/Arctic	2,982	2,603	2,853	411	6.9

Notes: Single Family cost and condo cost and average energy savings from PNNL. Upfront cost derived by HUD and simple payback calculated by HUD. HUD does not have the underlying estimates for different types of units for the update from 2018, only the average across single family and low-rise multifamily.

The average simple payback of the 2018 to 2021 update varies significantly across climate zones. Comparing the simple paybacks with the present value multipliers (in Figure 6), net present value benefits would be generated for Climate Zones 1, 2, 3, 7, and 8 in all of the specified. In Climate Zone 6, changing standards from the IECC 2018 to the IECC 2021 produces net benefits in all scenarios except the least favorable: a 20-year lifetime, discount rate of 7 percent, and negative energy price growth. The update of IECC from 2018 to 2021 may be the least advantageous in Climate Zones 4 and 5. For Climate Zone 5, with a simple payback of 16.5 years, the net benefit of the investment is positive only for lower discount rates (3 percent) and if the lifetime of the construction is at least 25 years.

The dollar value of the present value of the energy savings over 30 years is shown in Figure 13 for four scenarios (for discount rates of 3 percent and 7 percent, and real energy price growth of 0 percent and 1 percent). The present value of energy savings over 30 years of the national average is $3,900 discounted at 3 percent, and $2,500 discounted at 7 percent. The savings range by climate zone from $2,500 in Climate Zone 6 to $8,300 in Climate Zone 8. Assuming annual energy price growth of 1 percent, the present value of energy savings over 30 years would be greater, at $4,400 (discounted at 3 percent) and $2,800 (discounted at 7 percent).

Figure 13. Incremental Energy Savings of IECC 2018 to IECC 2021 ($/per Average Dwelling, Lifetime of 30 Years)

Area	Incremental Cost	No Real Energy Price growth		Real Energy Price Growth of 1%	
		PV discounted at 3%	PV discounted at 7%	PV discounted at 3%	PV discounted at 7%
National Average	**2,010**	**3,900**	**2,500**	**4,400**	**2,800**
Climate zone 1	940	4,000	2,700	4,600	2,900
Climate zone 2	1,400	3,900	2,500	4,400	2,800
Climate zone 3	1,630	4,000	2,700	4,600	2,900
Climate zone 4	2,960	4,100	2,700	4,700	3,000
Climate zone 5	2,860	3,500	2,300	4,000	2,500
Climate zone 6	1,350	2,500	1,600	2,800	1,800
Climate zone 7	2,850	6,200	4,100	7,000	4,500
Climate zone 8	2,850	8,300	5,500	9,400	6,000

Notes: To derive values of energy savings in columns, multiply first year savings by appropriate NPV multiplier (see Figure 6). PVs are rounded to nearest $100. Costs are rounded to nearest $10.

The net present value of the investment is the present value of the reduced energy expenditures less the incremental cost of producing an energy-efficient unit. Over 30 years, the present value of the benefits from reduced energy expenditures outweigh the costs for all climate zones when the discount rate is 3 percent. When the discount rate is 7 percent, the average home in Climate Zones 4 and 5 does not break even within 30 years. For the scenario of real energy price growth of 1 percent annually, the NPV of the change in standards is positive for the average home in all climate zones except for Climate Zone 5 when the discount rate is 7 percent.

Discussion of Incremental Costs

Alternative estimates of the incremental costs of construction for the 2018 to 2021 were developed by Home Innovation Research Labs for NAHB. Their estimates were much higher than those of PNNL, attributable partly to the design of the model home and to assumptions concerning overhead and profit.[36]

Replacement costs of shorter-lived systems was not addressed in the primary estimate of costs. The ASHRAE analysis assumed a replacement cycle of every 15 years for HVAC components. Following their methodology, our 30-year planning horizon would involve one replacement of the efficiency option in the fifteenth year. The incremental cost of the IECC 2021 (from the IECC 2018) efficiency option ranges from $830 to $975. The present value of this cost in year 15 ranges from $548 to $645 if the discount rate is 3 percent and from $322 to $378 if the discount rate is 7 percent. It is possible that an equally efficient system would be less expensive in 15 years due to technological progress and becoming the industry standard.

Allcott and Greenstone (2012) point out that engineering costs tend to omit opportunity costs. Opportunity costs can include the loss of capital or staff used for energy efficiency investment over

[36] See Appendix D: NAHB Estimates of Construction Cost for an extended discussion.

alternative business decisions such as increases in production (Adisorn et al., 2020).[37] These opportunity costs can be significant; one study found that nearly half of the investments that engineering assessments recommended for energy audits of medium-sized businesses were not implemented due to these additional costs and risks.[38] At the same time, we can expect that builders will act to minimize the costs of the Notice by building slightly different designs if allowed by zoning rules and market demand.

Administrative compliance costs are not expected to play a role because HUD already requires that HUD-assisted households meet minimum standards.[39]

Homebuyers: Cash Flow Impacts from IECC 2021

One measure of cost-effectiveness used by PNNL to describe the impacts of a change in the IECC standard explicitly accounts for the cost of homeownership. The cash flow analysis describes the number of years until the accumulated energy savings outweigh the costs of financing a larger mortgage loan. The lifecycle cost approach is the discounted costs over the scheduled repayment period of the mortgage costs, energy bills, and other costs related to the energy efficiency.

A typical borrower does not pay the full incremental cost of construction upfront. Instead, in the first year, they make a down payment, which is only a fraction of the value of the home. The remaining portion of the incremental cost of construction is financed through mortgage debt. The interest on the loan and other loan fees are the cost to the consumer of delaying repayment.

The difference between this and the NPV approach to determining cost-effectiveness depends upon the relationship between a consumer's discount rate and the interest rate on which a mortgage loan is based. The net present value to the consumer becomes more favorable when the real interest rate is less than the discount rate; is equivalent when the interest rate and discount rate are equal; and is less favorable when the real interest rate is greater than the discount rate. [40] In the NPV analysis, without financing, a higher discount rate reduces the future benefits. In the mortgage analysis, a high discount rate reduces both future benefits and costs. For comparability with the NPV approach, the mortgage analysis would have to avoid any transaction costs or other costs not included in that replacement. The only difference would be that the majority of the costs would be paid over the lifetime of the loan instead of upfront.[41]

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[37] Some studies criticize the NPV as too simplistic of an investment criterion for energy-efficient investments (for example, Basher and Raboy, 2018). Price volatility should make it optimal for the investor to wait and collect more information before acting to invest. We do not, however, expect that this type of uncertainty will delay energy-efficient investment. And so, the loss of the real option is not a significant opportunity cost. Randomness in real estate prices will dominate energy prices in land development decisions. Uncertainty may however make someone less likely to adopt energy efficiency.

[38] A study of free energy audits that the U.S. Department of Energy provides to small businesses found that many investments which engineering assessments showed would have short payback periods were not adopted due to opportunity costs or other unaccounted costs, such as lack of staff for implementation, risk of inconvenience to personnel, or suspected risk of issues with equipment (Anderson and Newell, 2004).

[39] For a discussion of the role of administrative costs in slowing energy-efficient investment, see Lades et al. (2021).

[40] To see this relationship, a mortgage payment can be derived by dividing the original loan amount by the appropriate present value multiplier.

[41] See Appendix C for an algebraic treatment.

The average borrower will have a discount rate at least as high as the interest rate for them to realize gains from borrowing. [42] How interest rates diverge from consumer discount rates is critical to understanding whether mortgage finance of the incremental construction cost is affordable. One empirical examination of households found a long-run discount rate close to 3 percent and a short run discount rate of approximately 100 percent (Laibson et al., 2015). The short-run discount rate is between the present and the future. A benefit or cost would be valued at only half of what it is worth in the present. The long-run discount rate is between future years (for example, between year 2 and year 3). The decline in present value from the present to next year is precipitous and for every year afterwards declines more gradually. This formulation ("quasi-hyperbolic function") is used to explain consumer behavior that may seem like an anomaly: for instance, use of a credit card with a high interest rate concurrent with long-term wealth accumulation. The associated discount factors would be 1, 0.50, 0.49, 0.47 to 0.22 in year 30,[43] compared to the smoother series of an exponential discount factor at 3 percent: 1, 0.97, 0.94, 0.92 to 0.42 in year 30.

There are some differences between the average mortgage presented by PNNL and the average FHA mortgage, justifying the presentation of an original analysis. FHA loans allow for a higher loan-to-value ratio than qualified loans, are for smaller and less expensive homes, and the borrowers have lower income. All of these differences will affect the upfront costs of the loan, as well as the periodic costs. Upfront costs include the down payment, FHA's upfront insurance premium, and closing costs.

Another possibility is that the design of the building affects the interest rate charged by the lender. An and Pivo (2020) found a small but statistically significant reduction of the interest rate for green buildings.

Although the interest rate is the determining factor of the mortgage cash flow analysis, there are other factors that would influence a consumer's decision. We express these upfront costs as a fraction of the purchase price.

$$(1 - LTV) + ufmip \cdot LTV + f \cdot LTV$$

The loan is a proportion of the sales price given by the LTV ratio. The first term ($1\text{-}LTV$) is the down payment, the second term *ufmip* $x\, LTV$ is the upfront mortgage premium charged on the loan, and f is the sum of all of the transaction fees. The maximum LTV ratio is 96.5 percent for FHA loans, but 95 percent is more common. The average down payment is thus 5 percent of the purchase price (100 – 95). The upfront mortgage insurance premium charged by the FHA is 1.75 percent of the loan, or 1.66 percent of the purchase price (1.75% x 95%).[44] The last term f, transaction costs, cover a wide variety of closing costs expressed as a proportion of the loan. All fees add up to anywhere from 2 percent to 6 percent of a loan. In practice, some closing costs are fixed, such as the third-party fees relating to pest inspection, building inspection, appraisal, credit checks, flood determination, title search fees, notary fees, and attorney fees. These fixed fees would not increase with the size of the loan. Fixed charges by the lender include processing fees and underwriting fees. Variable fees from the lender include the loan

[42] Debt could be a choice of a borrower with low discount rates if they expect to have more liquidity in the future and to refinance.
[43] The present value of the sum of a constant annual flow over 30 years would be 10.9 times that amount.
[44] The upfront premium can be financed by adding it to the loan.

origination charge, or commission for mortgage brokers, at approximately 1 percent of the size of the loan. Altogether, the upfront costs would be 7.6 percent of the increase in sales price.

Periodic costs of homeownership are expressed in this analysis as annual costs. The mortgage payment on the loan is typically the largest periodic cost for a homeowner.[45] Most FHA mortgages are fixed-rate payments with a repayment period of 30 years. The mortgage principal and interest payment are determined so that the principal of the loan (given by the loan-to-value ratio) and accumulated interest on loan balance are entirely repaid by the end of the scheduled life of the loan.[46] For example, an economy-wide 3 percent interest rate would require a mortgage payment of 4.95 percent of the loan.[47] Interest rates have increased since the PNNL analysis was completed in 2021.

Figure 14. Mortgage Interest and Principal Payments (For a Fixed-Rate 30-Year Loan)

Real interest rate (%)	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
Annual Mortgage Payment (% of loan)	4.38	4.66	4.95	5.25	5.56	5.87	6.20	6.52	6.85

Property owners pay local property taxes on the assessed value of a home, the rates of which vary significantly by locality. State averages vary from approximately 0.25 percent in Hawaii to 2.5 percent in New Jersey. PNNL assumes a property tax rate of 1.24 percent, which is reasonable. HUD's estimate is slightly higher, at 1.5 percent, to account for regressivity in assessment practices (Berry, 2021). It is also possible that later assessments of similar homes would not register energy efficiency if the HUD home were significantly above area norms – making 0 percent a credible estimate of the incremental tax rate. Note that property taxes are not included as a cost in the present value analysis and so the cash flow and NPV are not comparable when a cost is included in one but not the other. It could also be argued that property taxes are a transfer to the local government, used to create a public benefit, or may be capitalized in the price of the home, and so should not be counted.

The possibility of deducting mortgage interest and property taxes from federal income taxes can reduce the direct cost of ownership. It is unlikely, however, that many FHA-insured borrowers would take

[45] Note that even if the buyer does not borrower, the real interest rate represents the opportunity cost, and is thus a component of the user cost of capital. The principal payment portion of the mortgage payment does not represent an additional cost because the mortgagor receive equity in return. Rather, it reflects how the incremental construction cost has been rescheduled from an upfront to periodic payment. It could be argued that the payment of the principal could be treated as an addition to wealth. For example, the BLS consumer expenditure survey categorizes the principal payment as a financial flow and not as a housing cost. Accounting for the addition to wealth would lower the estimated economic costs to the borrower. Further complicating matters, the change in cost to the borrower should be based on the change in purchase price of a home rather than the change in construction cost. A homebuyer would be willing to pay up to their perceived value of the energy efficiency improvements, which may be more or less than the additional construction cost.

[46] The solution is given by the quality between the original loan and the present value of mortgage payments over the life of the loan discounted at the interest rate. The assumed loan dynamics is that the loan balance at the end of a year includes interest on an amount equal to the loan balance at the beginning of the year less the mortgage payment: $L_{t+1} = (1+r) \times (L_t - m)$.

[47] These amounts can also be calculated from the Excel payment function as -PMT(r,30,1/(1+r)). We divide the present value by (1+r) to reverse the discounting of the first year's mortgage payments because we treat the first payment as occurring in the first year.

advantage of the mortgage interest income deduction. Exceeding the standard deduction of $25,100 for a household of two would require that there be many other deductions or that the loan is large, and the interest rate high.[48] Also, households can deduct the interest portion of the mortgage payment only; as the loan is paid, so is deductible interest. Thus, HUD assumes that the mortgage interest and property taxes are not deducted from income taxes. Even if the costs were to be deducted from income taxes, the cost burden would only be borne by the Treasury and would still have to be accounted for.

FHA-insured homebuyers pay a periodic mortgage insurance premium in addition to the upfront mortgage insurance premium. The premium can take on different values varying from 45 to 105 basis points depending upon the LTV, term of the loan, and initial value of the loan. Our model loan is assumed to be a 30-year loan with an LTV of 95 percent. A loan with such terms would be charged an annual mortgage insurance premium of 80 basis points (0.8 percentage points), if no more than $625,000, and 100 basis points if greater than $625,000. We assume 0.8 percentage points.[49]

Other financial costs related to homeownership include property insurance and flood insurance. FHA-insured borrowers are required to purchase property and hazard insurance. A lender could demand that a borrower have homeowners (or hazard) insurance that covers the loan amount. In this case, an increase in construction cost could add to the coverage required by the lender. Otherwise, a borrower can choose a specific level of coverage, not necessarily as high as the replacement cost. Flood insurance through the National Flood Insurance Program is limited to $250,000 and so any increases will not affect the cost for homes at the maximum insurable value. We assume that the change in insurance costs is zero.

Physical costs include maintenance of the home or depreciation if no reinvestment occurs. HUD does not have the same information used by PNNL to estimate the cost of repairs. We considered a general depreciation rate of 1 percent of the added value of the home[50] equal to the incremental cost of construction. Instead, we opted to model the declining productivity as a shorter lifespan than the building itself.

Offsetting the cost of homeownership is the real appreciation of home values which, if positive, adds to the wealth of the owner. Should the energy-efficient investment be expected to appreciate at the same rate as land values? Not necessarily. Rather, the value of energy-efficient components should be expected to increase with the demand for residential energy, which is linked to the demand for space, but is not the same. A concern is double counting the impact of an increase in energy prices, which is modeled under the assumption concerning the PV of energy efficiency. We assume that it is zero.

Inflation is not explicitly considered in this analysis. If it were, inflation would factor into the nominal interest rate and the nominal appreciation rate. When the income tax deduction is low (or zero) and the LTV is high (as it is for FHA loans), then inflation cancels out. The following is expressed in real terms (adjusted for inflation).

$$\left(1 - t_y\right) \cdot (m \cdot LTV + \tau) + amip \cdot LTV + \delta - v$$

[48] Loan limits for single family homes are approximately $400,000 in low-cost areas and $1,000,000 in high-cost areas.
[49] https://www.hud.gov/sites/documents/15-01MLATCH.PDF
[50] https://www.huduser.gov/periodicals/ushmc/summer2000/summary-2.html

The change in price is assumed to be equal to the change in construction costs. There are reasons that this could be higher or lower than the cost to the builder, depending upon market conditions and bidding for energy efficiency. Another factor that could lead to a different change in price is the capitalization of credit–debt at favorable terms allows borrowers to pay more than they would otherwise. Any consumer surplus would go into a higher bid.

Figure 15. Parameters for FHA Borrower Cash-flow Analysis

Variable	Symbol	HUD Estimates
Upfront Costs		
Loan-to-value ratio	LTV	95%
Upfront mortgage insurance premium	$ufmip$	1.75%
Variable loan fees	f	1%
Periodic Costs		
Tax deduction rate	t	0%
Real Interest Rate	r	3%
Principal and Interest Payment	m	4.95%
Mortgage Lifetime	---	30 years
Mortgage Type		Fixed rate
Property Tax Rate	τ	1.5%
Depreciation	δ	0%
Annual Mortgage Insurance Premium	*amip*	0.8%
Real Appreciation	v	0%
Discount Rate	ρ	3%, 7%

Note: The change in price is assumed to equal the change in construction costs, implying a pass-through rate equal to 1.

In our first scenario of the consumer, with a 3 percent discount rate and the IECC update from 2009, the increase in price is $5,555; the increase in the loan is $5,277, given by the LTV (or 95 percent of the increase in price). An average incremental increase in the loan translates to an approximate 2 percent increase of the median loan of a newly built FHA-insured home (in 2020).[51]

Figure 16. Mortgage Amount of FHA-insured Single-Family Homes - New Construction ($)

Fiscal Year of Endorsement	Mean Loan Amount*	Median Loan Amount*
2019	254,000	241,000
2020	264,000	249,000
2021	280,000	265,000
2022	310,000	299,000

*Rounded to nearest $1,000

The upfront loan cost is equal to the sum of the down payment (5 percent of the price) plus the upfront mortgage insurance premium (1.75 percent of the loan), and variable closing costs (1 percent of the loan value). The principal and interest period is assumed to be fixed, scheduled over 30 years, and based on a real interest rate of 3 percent, equaling $261 for a loan of $5,277. Other periodic costs are property

[51] Because the construction costs will be lower for smaller homes, then the actual estimate will be somewhat smaller – perhaps 10 percent lower.

taxes, 1.5 percent of the increase in price ($83), and the annual insurance premium, which is 0.8 percent of the current loan balance. The annual premium is $42 in the first year and declines as the loan balance falls. The total periodic loan costs in the first year are $387 and decline by about $1.00 every year as the annual insurance premium declines. In the first year, total costs are $810 (upfront plus periodic). Every year the energy savings are assumed to be $752, and, in this conservative scenario, they do not increase over time. The present value of all benefits is approximately $15,000 and is nearly $8,000 for all associated costs.

Figure 17. Cash Flow Analysis for IECC Updates
Single Family Home
(Combining IECC Energy Reduction and Cost Estimates with FHA Loan Parameters)

	2009 – 2021 IECC Update		**2018 – 2021 IECC Update**	
	3%	**7%**	**3%**	**7%**
Price	5,555	5,555	2,372	2,372
Loan	5,277	5,277	2,253	2,253
Upfront Loan Cost	423	423	181	181
Mortgage Payment	261	261	112	112
First Year Periodic Cost	387	387	165	165
First Year Periodic Benefit	752	752	210	210
PV Benefits 30 Years	15,182	9,985	4,240	2,788
PV Costs 30 years	7,944	5,414	3,392	2,312
	Cash Flow of Mortgagor			
First Year Cash Flow	-58	-58	-136	-136
Second Year Cash Flow	366	342	45	45
PV after 5 years	1,308	1,186	34	19
PV after 10 years	2,820	2,349	228	168
PV after 20 years	5,310	3,802	565	364
PV after 30 years	7,237	4,570	847	476
	NPV Analysis in the absence of debt financing			
PV No loan after 30 Years	7,945	3,323	1,149	-56

The cash flow facing the household is the equivalent of the energy savings less the additional costs to the household. In the first year, there is a loss of $58 ($752 – $810). In the second year, there is a positive flow of $366 ($752 - $386). The present value (discounted at 3 percent) of the cumulative cash flow after the first five years is approximately $1,300; it is $2,820 after 10 years, $5,310 after 20 years, and $7,240 after 30 years. Similar estimates by climate zone and at a 5 percent interest rate can be found in Appendix I.

For the sake of comparison, we show the NPV of the investment had the homebuyer been able to finance the increase in cost without a loan. This figure is equal to the PV of energy savings less the upfront cost of construction less the present value of property taxes.[52] The NPV is slightly higher for the no loan scenario because the borrower is able to avoid some of the additional fees associated with the

[52] The initial measure of the NPV of the energy investment did not include the cost of property taxes. The difference between the NPV of the project over 30 years in Figure 7 and Figure 17, is the present value of property taxes. All user costs must be included for the consistency.

loan. However, for the borrower with a higher discount rate and the equivalent scenario, debt is more advantageous than equity.

Including estimates of replacement costs can affect whether the cash flow is positive or negative when the PV is relatively small. The PV of the additional replacement costs, occurring in year 15, is on average $600 for a 3 percent discount rate and $350 for a 7 percent discount rate.[53] The present value of the cash flow after 20 years for a borrower with a 3 percent discount rate would become negative ($565 - $600) and remain just above zero for the borrower with a 7 percent discount rate ($384 - $350). The PV of the borrower's cash flow after 30 years would remain positive for the IECC 2018 to 2021 update. The IECC 2009 to 2021 update is much more tolerant and could absorb replacement costs in year 15 as high as the incremental costs of construction.

As discussed earlier, the costs and benefits are likely to be lower for smaller homes. Figure 18 shows the PV for the mortgage borrower over 30 years for different combinations of cost and benefit adjustments. All costs and benefits are proportional, and so can be derived from discounting the PV of costs and PV of benefits by the assumed reduction for the PNNL base case.

Figure 18. PV of Cash Flow Analysis for IECC Updates Over 30 years For Single-Family Homes Adjusted for Lower Square Footage ($)

	2009 – 2021 IECC Update		**2018 – 2021 IECC Update**	
Scenario	**3%**	**7%**	**3%**	**7%**
PNNL Base Case	7,237	4,570	847	476
5% Lower Energy Savings, 10 % Lower Costs	7,273	4,613	975	568
5% Lower Energy Savings, 5% Lower Costs	6,876	4,342	806	452
10% Lower Energy Savings, 10 % Lower Costs	6,514	4,114	763	428
10% Lower Energy Savings, 5% Lower Costs	6,117	3,843	594	313

The base case is the PV of the mortgage analysis using the PNNL estimates concerning construction costs and energy savings. The other rows show the NPV for different IECC updates and for different discount rates across a sensitivity analysis for smaller homes. A smaller home will consume less energy; we assume a reduction of 5 to 10 percent. The PV of benefits will fall accordingly. The same is true for construction costs. For example, consider the IECC 2009 to 2021 update for a consumer with a 3 percent discount rate. If energy savings are 5 percent less and costs 10 percent less for a smaller home, then the PV of energy savings would be $14,423 (95 percent of $15,182), the PV of costs $7,150 (90 percent of $7,944), and thus the net present value equal to $7,273 ($14,423 - $7,150), which is slightly higher than the NPV for the larger home. The least advantageous NPV is $313 for the 2018 to 2021 update, for which the borrower has a discount rate of 7 percent: energy savings are reduced by 10 percent, and costs are increased by 5 percent. These results are meant for illustrative purposes only and as a

[53] HUD does not have an estimate or replacement costs for the 2009 to 2021 IECC update.

sensitivity analysis. To calculate the aggregate impacts of the IECC update, we use the adjusted benefits and costs as reported in Appendix F.

Comparison with PNNL Estimates of Life-Cycle Cost

PNNL estimates the life-cycle cost savings (LCC) as a primary cost-effectiveness test of the standards. The LCC captures the extent to which additional measures pay for themselves through energy cost savings over the course of a typical 30-year mortgage. The life-cycle cost is a net change in overall cash flows over this period discounted to the present value.

For single-family housing, average national LCC savings are estimated to be around $15,000 per housing unit for adoption of the latest 2021 IECC over the 2009 IECC. Average LCC savings vary considerably by climate zone, from as low as $8,000 in Climate Zone 2 to a high of $47,000 in Climate Zone 8. These LCC estimates are higher than HUD's NPV estimates, which range between roughly $5,000 and $8,000, or between $4,000 and $7,000 for a smaller single-family home.

For the 2021 IECC compared to the 2018 IECC, a weighted national analysis across both single-family and multifamily units estimates life-cycle cost savings of approximately $2,000 per dwelling unit. This ranges from around $1,000 in Climate Zone 6 to almost $7,000 in Climate Zone 8. Again, these estimates are higher than HUD's NPV estimates, which range between $400 and $900 for single-family homes or between $300 and $1,000 for smaller single-family homes.

With full take-up, low-rise multifamily housing is estimated to experience LCC savings of approximately $5,000 per unit on average; this ranges from $4,000 in Climate Zone 2 to $15,000 in Climate Zone 8.

Cash Flow for USDA-Guarantee Programs

USDA loan programs help approved lenders make 100 percent-financed, zero downpayment mortgage loans in providing low- and moderate-income households the opportunity to own adequate, modest, decent, safe, and sanitary single-family homes as their primary residence in eligible rural areas. Program lending extends to 100 percent of the property's appraised value, not the purchase price. Borrowers potentially can include closing costs and home repair expenses into the financing. In addition to closing costs and eligible repairs, funds can be used for reasonable and customary expenses associated with the purchase, including items such as utilities connection fees, tax and insurance escrows, essential household equipment, and site preparation. Other requirements include a 30-year fixed rate term[54], no set maximum purchase price, eligibility based on an applicant's repayment ability, no set acreage limits (although acreage must be considered common for the area), and no "seasoning" requirements (i.e., provided they are otherwise eligible, "flipped" properties are allowed). There is no loan limit under Guaranteed Loans, but under Direct Loans, the house must be "modest"[55], decent, safe, and sanitary, and regardless of repayment ability, applicants may never borrow more than the area loan limit.

There are no significant upfront costs for the borrower under these USDA programs[56] since there is no downpayment requirement. Other closing costs could be financed by adding to the total loan amount.

[54] Under the Direct Loan Program, loans are for up to 33 years but could be extended to 38 years for those with incomes below 60 percent of the area median household income. Also, interest rates are determined so that a family pays between 22 and 26 percent of their income for principal, interest, taxes, and insurance.
[55] Modest is defined by dollar limits, and the house must be less than 2,000 square feet.
[56] A very minimal fee, like a $25 credit report fee, is due payable. All other typical fees may be part of the loan.

With no downpayment requirement, USDA loans allow for a 100 percent loan-to-value ratio. However, borrowers who choose to make a downpayment can have seller contributions (or contributions from other interested parties) to the downpayment as long as they do not exceed 6 percent of the sales price.

USDA loans require two types of mortgage insurance: a one-time upfront guarantee fee of 1 percent of the loan amount and an annual fee of 0.35 percent of the loan's balance that serves as the monthly mortgage insurance premium. Although there is an upfront insurance premium which is paid at closing, this, too, could be financed into the total loan. The annual fee is lumped into the monthly payment and is paid for the life of the loan. Other financial costs related to homeownership include property insurance and flood insurance.

Since all of the costs including the incremental cost of construction are financed through mortgage debt, the interest on the loan and other loan fees are the cost to the borrower of delaying repayment. Note, however, that USDA mortgage interest rates are lower than FHA and conventional loans. On average, USDA mortgage interest rates are around 0.5 to 0.75 percent lower than FHA and conventional loans. Also, USDA borrowers may have lower incomes than borrowers with FHA-insured mortgages and conventional loans since the programs target very-low to low-income households (for Direct Loans) and moderate-income households (for Guaranteed Loans) in eligible rural areas.[57]

Cash Flow for Renters

Renters who do not purchase a home do not directly pay for the additional costs of meeting energy efficiency standards. Instead, these costs fall on the owner of the home. If the owner is not an occupant and does not directly benefit from the energy savings, they may choose to pass on the incremental construction costs to their tenant in the form of higher rents. For renters, their lowered energy costs and higher rents may balance out.

Low-Rise Multifamily

Energy standards for multifamily buildings are established in the IECC for low-rise buildings with up to three floors. Most HUD-assisted multifamily buildings are less than three floors and would thus adhere to the IECC standards. As explained earlier, states have adopted and currently maintain different versions of the IECC and ASHRAE 90.1 standards, which will affect aggregate costs and benefits. In addition, many HUD-assisted multifamily properties receive Low Income Housing Tax Credits (LIHTCs), which often meet or exceed the proposed standards. While LIHTC buildings must comply with state adopted minimum standards, almost all states require, or provide incentives for builders to follow, a higher energy efficiency standard. This further lowers the compliance cost and the number of affected buildings.

Geographically, small building multifamily homes are most highly concentrated in New England and the Middle Atlantic (Obrinsky and Walter, 2016). Market research conducted in Washington, Minnesota, Illinois, and Oregon found that mid-size cities and suburbs experienced more construction of low-rise buildings as compared to larger cities or rural areas.[58] Low-rise buildings are more common for affordable housing development.

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[57] Verified income of all household members cannot exceed the income limit for the desired county.
[58] Ecotope, 2020. Residential Building Energy Efficiency Field Studies: Low Rise Multifamily. https://www.osti.gov/servlets/purl/1656655

For low-rise multifamily buildings, PNNL estimates an average incremental cost of adopting the 2021 IECC over the current 2009 baseline of $2,306 per unit. PNNL estimates $5,265 LCC savings for low-rise multifamily housing. LCC savings vary considerably from $4,064 in Climate Zone 2 to a high of $15,452 in Climate Zone 8. The simple payback average is 7.5 years. Simple paybacks range from a low of 5.1 years in Climate Zone 8 to a high 8.1 years in Climate Zones 2 and 3. Higher incremental or added costs typically translate into higher annual savings, with annual positive cash flows ranging from $145 to $525.

Aggregate Incremental Impacts of IECC Update

The aggregate effects of updating energy efficiency standards are dynamically complex. Most of the costs are upfront and experienced the year of construction. The benefits are experienced as a steady flow over the project's lifetime. For comparability of the aggregate costs and benefits, we present predicted effects in two distinct formats: the present value of all quantified effects and the annualized value of all quantified effects. In the present value approach, all economic effects over the course of a project's lifetime are isolated to the year of a cohort's construction. The upfront incremental cost of construction, as well as the present value of future incremental benefits, are counted as occurring the year the building is put in place.[59] There is no overlap between different cohorts (buildings put into place at different years).

The annualized approach compares the stream of benefits, annual energy saving, and annual emissions reduction, with the annualized incremental cost of construction. The annualized approach is logical for the real estate industry in which loans allows builders and buyers to spread the costs of construction over time.[60] By definition, the annualized flow effects for any cohort will be lower than the total present value. A primary difference in the annual effect analysis, however, is that the annual flow of benefits and costs is not limited to one cohort in a particular year. The total flow of benefits stems from all existing buildings built under the new standards. As time progresses and the stock of energy-efficient buildings expands, then so will the aggregate annual benefits from reducing energy consumption. The progression over time of the aggregate impact will depend upon the difference between the standards of the Notice and the practices mandated by local governments or adopted by industry. For example, if many of the larger states adopt IECC 2021 after three years, then the peak annual impact of the updated HUD-USDA standards could be in the second year.

All results are presented for the 3 percent and 7 percent discount rates, as well as the internal rate of return. We show the internal rate of return to illustrate what the discount rate would have to be for the net present value of the energy-efficient investment to break even. If the allocation of resources is optimal, then the marginal benefits of investment would equal the marginal costs. Adopting the internal rate as the discount rate implies that the allocation of energy efficiency is optimal. There are reasons to believe, however, that the allocation of energy efficiency is undersupplied, in which case the marginal benefits would be greater than the marginal costs. If the scenario analyzed calls for efficiency in a sector (lack of market failures), then the discount rate will be set at the break-even IRR. If a market failure or barrier is assumed for a sector, then using the 3 or 7 percent discount rate for the analysis yields marginal social gains.

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[59] If there were no market inefficiencies, then the benefits would be counted as the incremental change in sales price.

[60] The annualized cost is a close approximation of the mortgage payment when the down payment and other charges are relatively low.

We develop an estimate for the number of units affected by the rule. Every state has adopted a version of the IECC; a version of the IECC with amendments; their own energy efficiency standard, whose effects can be compared to a version of the IECC; or no energy efficiency standard. The minimum for HUD and USDA-assisted properties is the 2009 IECC from the previous 2015 Notice. No incremental effects will arise in California, where the energy code is similar to, or stronger than, the IECC 2021 standard. There are also intermediate cases in states that have adopted either the 2012, 2015, or 2018 IECC codes. HUD simplifies all other changes as equal to either the incremental change from 2009 or 2018 and assumes that there are no incremental effects in California, Washington, and Vermont. The incremental effects will apply to approximately 150,000 newly built units annually, most of which are in states with standards equivalent to the 2018 IECC. All data for the aggregate analysis can be found in Appendix F.

Figure 19. Assumed Typical Year of HUD and USDA-assisted New Construction Covered by IECC

Assumed Equivalency	Number of Units Annually
2009 to 2021 IECC	99,100
2018 to 2021 IECC	51,200
At 2021 IECC	10,300
All Units	160,700
Affected by 2021 Update	**150,300**

The energy saving from the IECC is derived from estimates by PNNL but adjusted for the square footage following the method described in Appendix B. The incremental costs of construction are adjusted by the same percentage as the energy saving.[61]

We present the costs and internal benefits according to an informal classification of housing management type, which we developed to categorize incentive incompatibilities that may lead to inefficient provision of energy-efficient investment. This classification is entirely conceptual and is used neither by HUD nor USDA. Instead, separating housing and housing construction by an informal categorization of the type of management is intended as a tool to understand the kind of market failures that may arise.

The aggregate costs are the aggregate incremental construction costs for one cohort of newly built homes. The aggregate is developed by multiplying the number of units affected by an assumed IECC change by the incremental cost associated with that change. The incremental costs vary by type of housing and the change in IEEC. More units will fall under the update from 2018 than 2009, but the incremental cost is higher for the update from 2009. The aggregate upfront incremental cost for the IECC update is expected to be as high as $553 million. The aggregate upfront incremental construction cost is converted to annualized incremental costs for comparability with the incremental annual energy savings. Converted to an annual flow over thirty years, the cost of construction to comply with IECC

[61] There is no technical or economic reason to assert that total incremental costs should vary with square footage by the same proportion as energy efficiency. However, we expect that, similar to energy saving, a proportional change in square footage will lead to a less than proportional change in incremental costs because of the fixed costs of the standards. Also, our simulation of construction costs for a smaller home (presented in detail in Appendix B) illustrates this point using PNNL estimates for larger homes.

2021 would be approximately $27 million annually (at a 3 percent discount rate) or $42 million annually (at a 7 percent discount rate).

Figure 20. Aggregate Costs for One Cohort of New Construction – IECC 2021

Sector	Upfront Costs ($)	Annualized at 3 % over 30 years ($)	Annualized at 7 % over 30 years ($)
Govt-managed	12,762,000	632,000	961,000
Privately managed Rental	33,642,000	1,666,000	2,534,000
Owner-Occupied	506,568,500	25,092,000	38,152,000
Total	552,972,500	27,390,000	41,647,000

Aggregate annual energy saving is calculated similarly to aggregate costs, multiplying unit totals by the appropriate average benefit per unit. The incremental annual savings of approximately $45 million are converted to a present value over 30 years for comparison with the upfront construction costs: $1.48 billion with a discount rate of 3 percent and $972 million with a discount rate of 7 percent.

Figure 21. Aggregate Energy Savings for One Cohort of New Construction – IECC 2021

Sector	Annual Energy Savings ($)	PV over 30 years discounted at 3 % ($)	PV over 30 years discounted at 7 % ($)
Govt-managed	1,736,000	35,046,000	22,968,000
Privately managed Rental	4,406,000	88,956,000	58,068,000
Owner-Occupied	66,945,000	1,351,511,000	890,498,000
Total	73,087,000	1,475,513,000	971,534,000

For the ease of the reader, we regroup the aggregate impacts within a consistent timeframe, either annual or present value impacts.

Figure 22. Aggregate Annual Impacts of IECC 2021 Update Per Cohort (S)

Sector	Annual Energy Savings ($)	Annualized Costs at 3% ($)	Annualized Costs at 7% ($)
Govt-managed	1,736,000	632,000	961,000
Privately managed Rental	4,406,000	1,666,000	2,534,000
Owner occupied	66,945,000	25,092,000	38,152,000
Total	73,087,000	27,390,000	41,647,000

The total energy saving exceeds the annualized cost for the 3 percent and 7 percent discount rates. The incremental benefits in terms of private gains are approximately 2.7 times the annualized costs at a 3 percent discount rate and 1.8 times the annualized costs for a 7 percent discount rate. These benefits do not include the public benefit of reducing damages from greenhouse gas emissions. The annualized costs would be greater for shorter time horizons and higher discount rates.

The annual effects will increase as more cohorts are added to the stock of HUD- and USDA-assisted energy-efficient housing. In the second year, with two cohorts put into place, there could be a stream of almost $150 million (future value) of energy savings. The number of units affected every year will decline as states update their standards to IECC 2021 or industry adopts the prescribed standards. Thus, we expect the aggregate annual incremental effects to taper off. The maximum annual effect of all cohorts is not likely to exceed somewhere between three or four times the annual effect of one cohort, but it is possible that the aggregate annual benefit summed over cohorts could exceed $100 million at some point within the first five years.

Figure 23. Aggregate Present Value Impacts of IECC 2021 Update Per Cohort ($)

Sector	Upfront Costs	PV Energy Savings over 30 Years at 3%	PV Energy Savings over 30 Years at 7%
Govt-managed	12,762,000	35,046,000	22,968,000
Privately managed Rental	33,642,000	88,956,000	58,068,000
Owner occupied	506,568,500	1,351,511,000	890,498,000
Total	552,972,500	1,475,513,000	971,534,000

The present value of private energy savings for just one cohort of HUD and USDA-assisted construction from adopting the 2021 IECC is significant: from approximately $972 million (at a 7 percent discount rate) to $1.48 billion (at a 3 percent discount rate). The private benefits in terms of energy savings would be higher in the presence of real energy price growth (more than 0 percent) and a longer lifetime (more than 30 years). The public benefits are analyzed in a separate section of this analysis (see page 51). The incremental upfront construction costs from IECC are estimated to be approximately $550 million. These costs would be slightly higher if more accurate estimates concerning maintenance and replacement costs were included. Unlike the annual incremental effects of the rule, the present value effects of different cohorts should not be summed together. However, the aggregate present value impacts for future cohorts will decline as states and industry conform to the 2021 IECC standards.

A net present value of private benefits ranging from $900 million to $1.5 billion is significant. To accommodate the potential criticism that the net benefit estimates are unreasonably optimistic, HUD includes a detailed analysis of a variety of scenarios for IECC, in which the net present value gains range from $550 million to $630 million (see page 116).

Analysis of Update to ASHRAE 90.1

Overview

HUD-assisted and -insured multifamily buildings with over three floors are subject to ASHRAE 90.1 standards. Most of HUD's insured and assisted multifamily buildings have less than four floors and are thus subject to the IECC standards discussed previously. This section discusses the impact of updating HUD's energy efficiency standards for mid- and high-rise buildings to the 2019 version of ASHRAE 90.1.[62] The incremental costs and benefits associated with this update rely primarily on analyses of ASHRAE 90.1 standard updates published by the Department of Energy's Pacific Northwest National Laboratory (PNNL) and HUD estimates of affected buildings and units.

[62] A read-only copy of the 2019 ASHRAE 90.1 standards is available at https://ashrae.iwrapper.com/ASHRAE_PREVIEW_ONLY_STANDARDS/STD_90.1_2019.

Description of ASHRAE 90.1 Code Changes

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) maintains building standards for commercial buildings, including residential buildings with more than 3 floors. The ASHRAE 90.1 standard, Energy Standard for Buildings Except Low-Rise Residential Buildings, provides prescriptive energy efficiency standards. Compliance with these standards is voluntary, unless adopted by federal, state, or local jurisdictions. Most states and local jurisdictions either adopt the standards in full or with amendments. A few states and local jurisdictions maintain their own standards that may be similar to ASHRAE 90.1. Adoption at the state level is discussed below.

Figure 24. ASHRAE 90.1 Changes Included in PNNL's Cost-Effectiveness Analysis

90.1 Addenda	Description	ASHRAE Version 2010	2013	2016	2019
	Chapter 5 Envelope				
90.1-07f	Roof reflectance	X			
90.1-07am	Window and door air leakage	X			
90.1-07bf	Air barrier, air leakage	X			
90.1-10bb	Modifies building envelope requirements for opaque assemblies and fenestration. Adds new visible transmittance (VT) requirement.		X		
90.1-13ai	Prescribes lower solar heat gain coefficient (SHGC) for vertical fenestration in climate zone 0 and lower U-factors for vertical fenestration in climate zones 4 through 8.			X	
90.1-16aw	Revises prescriptive fenestration U and SHGC requirements and makes them material neutral				X
	Chapter 6 Heating Ventilating and Air Conditioning				
90.1-10aj	Increases efficiency of fractional horsepower motors =1/12 hp .		X		
90.1-10ba	Requires door switches to reduce mechanical heating or cooling when doors are open.		X		
90.1-10bi	Increases efficiency of smaller air conditioners and heat pumps.		X		
90.1-16g	Provides definition of "occupied-standby mode" and adds new ventilation air requirements for zones serving rooms in occupied-standby mode				X
90.1-16h	Clarifies that exhaust air energy recovery systems should be sized to meet both heating and cooling design conditions unless one mode is not exempted by existing exceptions				X
90.1-16ay	Provides separate requirements for nontransient dwelling unit exhaust air energy recovery				X
90.1-16bo	Adds definition of Standby Power Mode Consumption. Increases furnace efficiency requirements.				X
	Chapter 8 Power and Chapter 10 Other				
90.1-07bs	Receptacle on/off control	X			
90.1-07df	Elevator lighting and ventilation	X			
	Chapter 9 Lighting				
90.1-07by	General interior lighting power density (LPD)	X			
90.1-07x	Automatic lighting shutoff required, occupancy sensors option selected for prototypes	X			
90.1-07aa	Automatic lighting shutoff, type of occupancy sensor control required to be manual on/off rather than automatic on/off for some applications	X			
90.1-07cf	Stairwell lighting control	X			
90.1-07i	External lighting power	X			
90.1-10bh, co, cr, dj, dl	Modify Lighting Power Densities (LPD).		X		
90.1-10by	Increases application of some lighting controls and reduces lag time for occupancy sensors. Reformats lighting controls requirement presentation.		X		
90.1-13cg	Reduces exterior lighting power allowances.			X	
90.1-13ch	Reduces interior lighting power allowances.			X	
90.1-13do	Adds efficacy requirements for lighting installed in dwelling units.			X	
90.1-16bb	Changes interior lighting power density (LPD) requirements for many space types				X
90.1-16cg	Revises LPDs using the Building Area Method				X

Source: PNNL (2013), PNNL (2015), and PNNL (2020)

ASHRAE updates the 90.1 standards every three years. HUD regulations currently require compliance with the 2007 version. This Notice updates these requirements to the 2019 version. PNNL provides an overview of the changes applicable to residential apartment buildings in each of the ASHRAE 90.1 updates since the 2007 version. The standards contain 12 chapters, although the prescriptive standards are in chapters 5 through 10. The changes since 2007 lie primarily in the building's envelope (chapter 5); heating, ventilating, and air conditioning (chapter 6); and lighting (chapter 9).

Current State Standards

Each state maintains its own energy efficiency standards. Changes adopted and incorporated into the ASHRAE 90.1 standards affect building standards only after states or local jurisdictions adopt the new version. Almost all states base their energy efficiency standards on ASHRAE 90.1, but many also approve amendments to the published standards. In some cases, states may only adopt certain sections of updated ASHRAE standards. Figure A4 in Appendix A lists the state energy efficiency standards as of March 31, 2022. The second column, "Current Code," lists the latest adopted code, while the third column, "Effective Equivalent," lists the code equivalent after accounting for amendments to the currently adopted code. The determination of effective equivalent was made by the Department of Energy's Building Energy Codes Program.

Ten states do not have a statewide code, but rather allow local jurisdictions to choose their own codes. Eight states have adopted the 2007 version of ASHRAE 90.1, or its equivalent. Under HUD's new standards, HUD-assisted or -insured properties in these 18 states, with no statewide code or requiring only the 2007 version, would experience the largest difference between HUD requirements and state minimum requirements. Six states have adopted standards equivalent to the 2010 version of ASHRAE 90.1, and nineteen states currently enforce the equivalent to the 2013 version. Two states have adopted the 2016 version, and six states have adopted the 2019 version. For developers of HUD-assisted and -insured properties in these six states, there will be no effect on costs or benefits.

Construction Costs and Energy Savings of ASHRAE 90.1-2019

Figure 25 (see Table 9 in the Notice) provides PNNL's estimates of the incremental costs, annual energy savings and lifecycle net savings of adopting the specified version of the ASHRAE 90.1 standards, compared to the previous version. The estimates are calculated for a reference building of 33,740 square feet in five cities representative of their respective climate zones. For example, the incremental costs of complying with the 2010 standards compared to the 2007 version is $20,858 for the reference building across all climate zones. The cost of building to the 2013 standard compared to the 2010 standard ranges from $5,711 per building in climate zone 2A to $23,358 per building in climate zone 3B. Adopting the 2016 and 2019 standards lowers the initial construction costs because energy efficiency improvements allow for a lower capacity HVAC system. Thus, new HUD-financed buildings in any states that currently maintain 2013 or later standards are not estimated to encounter higher construction costs.

HUD-financed buildings in twenty-seven states, including Washington, D.C., are therefore not expected to experience an increase in costs due to the new requirements. Further, the aggregate of incremental costs is lower across all versions (which represent the equivalent of moving from the existing HUD standard of 2007 to the proposed 2019 version) for buildings in climate zone 2A. Climate zone 2A includes counties near the Gulf Coast, and, of these states, Arkansas and Louisiana currently have standards equivalent to 2007 or earlier.[63]

Estimating the incremental costs and benefits across states required simplifying assumptions. Each analysis of an ASHRAE 90.1 update was conducted based on the prevailing prices and technology at the time. Moving from the 2007 or 2010 version directly to the 2019 version would likely see lower costs due to voluntary technology adoption over the past decade. Another difficulty in combining the analyses is that the reference city used in the analyses for a specific climate zone occasionally changed. For climate zone 2A, for example, the analyses of the 2010 and 2013 updates used Houston as the representative city. The analysis of the 2016 and 2019 updates used Tampa as the representative city in climate zone 2A. The climate zone whose representative city did not change was 3B (El Paso). Thus, a direct comparison and aggregation of cost and savings over multiple updates is not wholly appropriate. However, this comparison is informative and provides a useful examination of the incremental costs and savings of adopting each new update and identifies the general effect of moving from the 2007, 2010, or 2013 versions to the 2019 version.

Figure 25. Costs and Savings of New Versions of ASHRAE 90.1 As Estimated by PNNL

		in current year dollars				
				Climate Zone		
		2A	**3A**	**3B**	**4A**	**5A**
2010	Incremental Costs	$20,858	$20,858	$20,858	$20,858	$20,858
	Annual Energy Savings	$1,608	$1,845	$1,498	$2,069	$2,593
	Lifecycle Net Savings	$20,400	$25,500	$18,300	$30,800	$41,800
2013	Incremental Costs	$5,711	$23,214	$23,358	$12,891	$19,577
	Annual Energy Savings	$3,119	$2,061	$2,119	$1,868	$2,083
	Lifecycle Net Savings	$59,600	$22,600	$23,800	$29,200	$28,500
2016	Incremental Costs	($18,175)	($17,353)	($17,944)	($12,430)	($24,614)
	Annual Energy Savings	$1,634	$1,537	$1,571	$1,391	$1,794
	Lifecycle Net Savings	$69,504	$66,130	$68,155	$56,683	$85,700
2019	Incremental Costs	($11,992)	($12,389)	($13,661)	($9,966)	($9,674)
	Annual Energy Savings	$1,747	$1,581	$732	$542	$522
	Lifecycle Net Savings	$89,411	$89,748	$73,891	$61,744	$60,732

Note: Amounts shown in red and in parentheses represent negative values, i.e., negative incremental costs.

Examining the changes in ASHRAE 90.1 versions by section provides a more nuanced indication of why states adopt only certain provisions and whether or not new construction in states that have adopted the 2013 or later version will face increased costs. Figure 26 shows the incremental construction cost for each version of ASHRAE 90.1 from 2010 through 2019 by section: 1) Heating, Ventilating and Air Conditioning (HVAC); 2) lighting; and 3) envelope, power and other. These estimates do not include maintenance or replacement costs over the life of a building.

[63] Louisiana requires buildings receiving Low Income Housing Tax Credits (LIHTCs) to build to the 2018 IECC. Neither Arkansas nor Louisiana has any REAC-inspected buildings constructed between 2017 and 2021 that contain more than four floors. Thus, the higher energy efficiency standards would likely have little or no effect on construction in these states.

As discussed above, moving from the 2007 to the 2010 version increased costs equally across all climate zones. Figure 26 and Figure 27 provide a breakout of these costs as well as the cost of subsequent editions by building component (HVAC, building envelope, lighting) in current year and 2021 dollars, respectively. The costs were primarily due to changes in lighting and envelope requirements. According to PNNL (2013), the 90.1 Envelope Subcommittee noted that the air leakage requirements were already common practice and thus, states adopting the 2010 version may not experience an increase in costs for this provision (p.4.31). The costs from these addenda were estimated to increase costs uniformly across all climate zones.

The 2013 update for apartment buildings primarily changed HVAC system and plant capacity. The updated standards also adjusted lighting power density and automated lighting control requirements, although the changes did not have an impact on costs. Finally, this update also changed insulation and fenestration requirements, which caused most of the increase in costs. Across climate zones, these addenda lowered HVAC costs in climate zone 2A, but increased HVAC costs in the other climate zones. The changes to the envelope increased construction costs across all climate zones. The costs increased the most in climate zones 3A and 3B and the least in climate zone 2A.

The 2016 update for apartments included changes to the envelope, HVAC, and lighting. The changes to the envelope standards reduced fenestration. The changes to the HVAC standards affected system and plant equipment capacity. The cost of HVAC systems decreased in all climate zones due to changes in envelope standards, which resulted in lower required HVAC capacity. The lighting addenda increased lighting power densities and unit lamp efficacy requirements, which allow a smaller and less costly lighting system. Overall, incremental HVAC and lighting construction costs decreased, while addenda to the envelope slightly increased costs for three of the studied climate zones.

Figure 26. Incremental Initial Construction Cost of ASHRAE 90.1 Standards by Climate Zone

in Current Year Dollars

ASHRAE 90.1 Standard	Building Component	Mid-Rise Apartment 2A	3A	3B	4A	5A
2010	HVAC	$0	$0	$0	$0	$0
	Lighting	$9,430	$9,430	$9,430	$9,430	$9,430
	Envelope, Power and Other	$11,428	$11,428	$11,428	$11,428	$11,428
	Total	**$20,858**	**$20,858**	**$20,858**	**$20,858**	**$20,858**
2013	HVAC	($586)	$1,926	$2,070	$1,631	$1,769
	Lighting	$0	$0	$0	$0	$0
	Envelope, Power and Other	$6,296	$21,288	$21,288	$11,261	$17,807
	Total	**$5,711**	**$23,214**	**$23,358**	**$12,891**	**$19,577**
2016	HVAC	($5,436)	($4,928)	($5,519)	($3,305)	($11,756)
	Lighting	($12,739)	($12,739)	($12,739)	($12,739)	($12,739)
	Envelope, Power and Other	$0	$313	$313	$3,614	($120)
	Total	**($18,175)**	**($17,353)**	**($17,944)**	**($12,430)**	**($24,614)**
2019	HVAC	$9,017	$8,864	$7,591	$11,427	$11,720
	Lighting	($21,989)	($21,989)	($21,989)	($21,989)	($21,989)
	Envelope, Power and Other	$980	$736	$736	$595	$595
	Total	**($11,992)**	**($12,389)**	**($13,661)**	**($9,966)**	**($9,674)**
Aggregate	HVAC	$2,995	$5,862	$4,142	$9,753	$1,733
	Lighting	($25,298)	($25,298)	($25,298)	($25,298)	($25,298)
	Envelope, Power and Other	$18,704	$33,765	$33,765	$26,898	$29,710
	Total	**($3,598)**	**$14,330**	**$12,611**	**$11,353**	**$6,147**

Note: Amounts shown in red and in parentheses represent negative values, i.e., negative incremental costs.
Sources: PNNL (2013), PNNL (2015), PNNL (2020), and PNNL (2021).

The 2019 update also included addenda for the envelope, HVAC and lighting. The only change in the building envelope revised fenestration factors. There are several changes to HVAC requirements, which are partially offset by the need for reduced system capacity and plant due to the revised envelope standards. The direct changes to HVAC requirements affect occupied standby controls, exhaust air energy recovery for ventilation systems, and furnace efficiency. The lighting addenda modify lighting power density, which resulted from technological improvements and indirect changes such as light levels recommended by the Illuminating Engineering Society.

Figure 27. Incremental Initial Construction Cost of ASHRAE 90.1 Standards by Climate Zone

in 2021 Dollars						
ASHRAE 90.1		**Mid-Rise Apartment**				
Standard	**Building Component**	**2A**	**3A**	**3B**	**4A**	**5A**
2010	HVAC	$0	$0	$0	$0	$0
	Lighting	$11,718	$11,718	$11,718	$11,718	$11,718
	Envelope, Power and Other	$14,201	$14,201	$14,201	$14,201	$14,201
	Total	**$25,919**	**$25,919**	**$25,919**	**$25,919**	**$25,919**
2013	HVAC	($682)	$2,240	$2,408	$1,897	$2,058
	Lighting	$0	$0	$0	$0	$0
	Envelope, Power and Other	$7,323	$24,762	$24,762	$13,099	$20,713
	Total	**$6,642**	**$27,002**	**$27,169**	**$14,996**	**$22,770**
2016	HVAC	($6,137)	($5,564)	($6,231)	($3,731)	($13,273)
	Lighting	($14,382)	($14,382)	($14,382)	($14,382)	($14,382)
	Envelope, Power and Other	$0	$353	$353	$4,080	($135)
	Total	**($20,520)**	**($19,593)**	**($20,260)**	**($14,034)**	**($27,791)**
2019	HVAC	$9,557	$9,395	$8,046	$12,111	$12,422
	Lighting	($23,306)	($23,306)	($23,306)	($23,306)	($23,306)
	Envelope, Power and Other	$1,039	$780	$780	$631	$631
	Total	**($12,710)**	**($13,131)**	**($14,480)**	**($10,564)**	**($10,253)**
Aggregate	HVAC	$2,738	$6,071	$4,222	$10,277	$1,207
	Lighting	($25,970)	($25,970)	($25,970)	($25,970)	($25,970)
	Envelope, Power and Other	$22,563	$40,096	$40,096	$32,011	$35,409
	Total	**($669)**	**$20,198**	**$18,349**	**$16,318**	**$10,646**

Sources: PNNL (2013), PNNL (2015), PNNL (2020), and PNNL (2021), adjusted by HUD to 2021 dollars

Costs and Benefits to HUD-Insured and Assisted Properties and Tenants

HUD estimates that approximately sixteen percent of HUD-assisted and -insured buildings contain four or more floors. This is based on the height of REAC-inspected properties constructed over the past 5 years, 2017 to 2021. This is only slightly less than the average size for all multifamily residential buildings constructed. In contrast, according to the Census of Construction, between 2017 and 2020[64], 23 percent of multifamily residential buildings contained four or more floors. Buildings with four or more floors, however, contain a larger share of units, simply because these buildings are larger in size. REAC-inspected buildings with more than four floors, constructed from 2017 to 2021, contain 40 percent of the multifamily units. According to the Census of Construction, nearly 60 percent of all multifamily units constructed between 2017 and 2020 are in buildings with at least four floors.

Figure 28 shows the expected incremental costs and net present value of lifetime energy savings resulting from the adoption of the 2019 version of ASHRAE 90.1. These estimates are based on the average annual number of newly constructed units in the affected HUD programs from 2019 to 2021 and state-specific incremental costs and lifetime savings per square foot as estimated by PNNL[65], inflated to 2021 dollars. Figure 28 assumes an average apartment size of 941 square feet, as reported

[64] 2020 is the most recent year reported in the Census of Construction.
[65] The reports are linked at https://www.energycodes.gov/national-and-state-analysis.

by Yardi Matrix data[66]. Based on PNNL's state-specific analysis, the developers of all multifamily buildings, regardless of the current state code, would have lower construction costs when building to the 2019 version of ASHRAE 90.1 compared to the current state code, with the obvious exception of developers in states which have already adopted the 2019 version. Total incremental costs based on current state codes and the annual expected number of affected units are estimated to be -$10.840 million for 17,117 units.

The net present value of energy savings is similarly calculated using annual energy savings per square foot from PNNL's state-specific analyses. Energy savings are expected to continue for 30 years. The net present value of the stream of benefits from a single year of construction ranges from $31.625 million assuming a 7% discount rate to $48.085 million assuming a 3% discount rate.

Figure 28. Incremental Costs and Energy Savings Resulting from Adoption of 2019 ASHRAE 90.1

Current ASHRAE 90.1 Standard	Number of States	Annual Number of Units Affected*	Total Incremental Costs	Net Present Value of Energy Savings	
				3% Discount Rate	7% Discount Rate
No Statewide Code	10	1,596	-$662,487	$21,397,225	$14,072,666
2007	8	1,458	-404,258	6,188,735	4,070,248
2010	6	1,838	-697,586	5,048,570	3,320,376
2013	19	9,569	-8,452,990	14,840,737	9,760,552
2016	2	1,232	-622,624	609,372	400,776
2019	6	1,424	0	0	0
Total	**51**	**17,117**	**-$10,839,945**	**$48,084,639**	**$31,624,618**

**Annual Average 2019-2021*

The cost estimate from adopting the 2019 version of ASHRAE 90.1 indicates that regardless of the current state code, all developers will decrease costs. Thus, one could reasonably assume that given the cost advantages of following the 2019 version, developers have already incorporated all or most of the updates. Further, many states require a higher standard for developers receiving Low-Income Housing Tax Credits (LIHTCs). To the extent that developers of LIHTC properties also construct affordable housing funded or financed by other federal programs, then they likely build all their developments to the same higher standard. In this case, HUD's adoption of ASHRAE 90.1-2019 would have no impact on costs or energy savings because they are already constructed to that level.

Another possibility is that developers have voluntarily adopted the cost-saving measures, particularly related to lighting, and HUD's enforcement of the 2019 version of ASHRAE 90.1 would increase costs related to the other updated provisions. Figure 29 lists the cost and benefits assuming developers of HUD-assisted and -insured properties have voluntarily adopted the 2019 lighting standards. In this scenario, HUD's adoption of the 2019 version of ASHRAE 90.1 increases upfront construction costs by $6.77 million and produces energy savings ranging from $13.7 million to $20.9 million.

[66] See https://www.rentcafe.com/blog/rental-market/real-estate-news/us-average-apartment-size-trends-downward.

Figure 29. Alternate Scenario – Lighting Standards Voluntarily Adopted Before Being Required

Alternate Scenario - Lighting Voluntarily Updated					
Current ASHRAE 90.1 Standard	Number of States	Annual Number of Units Affected*	Total Incremental Costs	Net Present Value of Energy Savings	
				3% Discount Rate	7% Discount Rate
No Statewide Code	10	1,596	$1,810,119	$8,710,630	$5,728,864
2007	8	1,458	1,728,246	3,804,666	2,502,278
2010	6	1,838	1,305,934	3,260,189	2,144,182
2013	19	9,569	1,480,440	4,872,188	3,204,372
2016	2	1,232	447,330	218,449	143,671
2019	6	1,424	0	0	0
Total	**51**	**17,117**	**$6,772,068**	**$20,866,123**	**$13,723,367**

**Annual Average 2019-2021*

Figure 30 presents the range of impacts expected from adoption of the 2019 version of ASHRAE 90.1. As explained above, based on the upfront incremental costs and lifetime energy savings as estimated by PNNL and current state building code requirements, if developers currently build to only the state minimum, or the HUD requirement for states that have not yet adopted at least the 2009 version, total incremental costs would decrease $10.8 million. The PV of energy savings in this scenario would range from $31.6 million to $48.1 million (depending on the discount rate). However, if developers have voluntarily adopted the latest requirements in ASHRAE 90.1-2019, HUD's adoption of this version would have no impact on construction costs or energy savings. Finally, if developers have voluntarily adopted only the lighting requirements of ASHRAE 90.1-2019, which represent most of the decrease in incremental costs, HUD's adoption of this version would subject developers to HVAC, envelope, and other requirements. This would increase construction costs $6.8 million and provide energy savings ranging from $13.7 million to $20.9 million (depending on the discount rate used).

Figure 30. Summary of ASHRAE 90.1 Impacts

Impact Scenario	Total Upfront Incremental Costs	Net Present Value of Energy Savings*	
		3% Discount Rate	7% Discount Rate
Based on Full PNNL Estimates	-$10,839,945	$48,084,639	$31,624,618
Assuming All Updates Voluntarily Adopted	0	0	0
Assuming Lighting Updates Voluntarily Adopted	6,772,068	20,866,123	13,723,367

**Calculated over 30 years*

Figure 31. Annualized Costs and Annual Energy Savings

Impact Scenario	Annualized Costs*		Annual Energy Savings
	3% Discount Rate	7% Discount Rate	
Based on Full PNNL Estimates	-$536,938	-$816,404	$2,381,789
Assuming All Updates Voluntarily Adopted	0	0	0
Assuming Lighting Updates Voluntarily Adopted	335,443	510,034	1,033,567

**Annualized over 30 years*

Benefits: Reduction of Greenhouse Gas Emissions

The primary non-energy co-benefits of reducing energy consumption are the avoidance of economic damages caused by emissions associated with the generation of residential energy. The effect of a decline in energy consumption is to reduce emissions of both pollutants (such as particulate matter) that cause health and property damage, and greenhouse gases (such as carbon dioxide, methane, and nitrous oxide) that cause global warming. In this section, HUD measures the value of reducing carbon dioxide, methane, and nitrous oxide emissions, preceded by a discussion of the "rebound" effect, or the phenomenon whereby making the use of energy cheaper can entice a household to consume more energy, negating some of the energy savings.

The social cost of greenhouse gas emissions (SC-GHG) is typically presented as a present value from the expected damages of emissions. The present value measure is appropriate because the emission itself is irreversible. The estimate of the damage from an emission varies by the discount rate and the year of emission. The estimated social cost of the emission is lower for higher discount rates because the adverse effects in the future are valued less. The cost of an emission is higher for later years because the marginal cost of GHG emissions is increasing. An energy-efficient unit produces a stream of present value damage reductions.[67] Unlike the private gain of energy efficiency, for which the annual effect is limited to the year it occurs, the annual public benefits of reducing energy consumption extends for decades.

The economic benefits in one year from a new energy efficiency standard depends on the resulting change in energy consumption, the GHG emissions, and the damage from GHG emissions.

Benefits per unit per year =
Reduced Energy Consumed per year x Emissions of GHG per Energy Consumed x Social Cost per GHG

PNNL estimates that, on average across the country, the 2021 IECC is expected to yield approximately 9 percent energy savings on average over the 2018 code. By structure type, the IECC is expected to yield energy savings of approximately 11 percent for low-rise multifamily units and 8 percent for single-family units. For high-rise multifamily units, the 2019 ASHRAE 90.1 is expected to yield 2.5 percent energy savings over the 2016 code. HUD-assisted or insured households living in single-family homes are estimated to use 74 MMBtu per year; this estimate drops to 39 MMBtu per year for those living in multifamily units.[68]

Using these consumption estimates, this translates to per-unit annual average energy consumption savings of 1 MMBtu for high-rise multifamily units, 4 MMBtu for low-rise multifamily units, and 6 MMBtu for single-family units. With rebound effects ranging from 10 percent to 30 percent,[69] these consumption reductions fall to between 0.7 and 5.4 MMBtu annually. The energy consumption

[67] The present value of all damage reductions during the lifetime of an energy-efficient home must be evaluated using the same discount rate as the annual present value reductions.
[68] See upcoming section "Change in Household Energy Consumption" for sources for these estimates.
[69] See upcoming discussion of rebound effects in section "Rebound Effect."

reduction translates to between approximately 70 and 500 kilograms of carbon dioxide equivalents[70] averted per housing unit per year.

Over the range of a structure's lifetime, taking into account discount rates of future benefits, the reduction in carbon dioxide, methane, and nitrous oxide emissions is estimated to yield annualized benefits based on median social costs of greenhouse gases between approximately $10 and $30 per unit. Using the upper bound of the estimates of social costs of greenhouse gases ups this to $30 to $90 per unit per year. While inputs including the lifecycle of the structure, the rebound rate, and the emission factor all affect the range of estimates, the largest uncertainty comes from the social cost of greenhouse gases, which can differ by an order of magnitude depending on the discount rate used. The greatest benefits come from the reduction in emissions of carbon dioxide.

The estimates presented here are more likely to be underestimates because they cover the change in technical efficiency from the 2018 to the 2021 IECC, and the 2016 to the 2019 ASHRAE 90.1. States and jurisdictions which have adopted energy efficiency codes below the 2018 IECC or 2016 ASHRAE 90.1 will see higher benefits from the update to the 2021 IECC and 2019 ASHRAE 90.1.

Figure 32. Annualized Value of Reduction in Greenhouse Gases (CO_2, CH_4, N_2O) Per Unit

	Low	Mid	High
Single-family unit	$ 8.89	$ 26.81	$ 81.47
Low-rise multifamily unit	$ 6.45	$ 19.46	$ 59.14
Mid-rise multifamily unit	$ 1.55	$ 4.69	$ 14.25
Average unit	$ 7.67	$ 23.41	$ 71.13

Notes: Assumes 30-year lifecycle, 30% rebound rate, and higher CO_2 emission factor. Low, mid, and high estimates correspond to social costs of greenhouse gases under discount rates of 5%, 3%, and 3% at the 95th percentile scenario, respectively.

Accounting for Damages Avoided

The damage from emissions is summed over time (*t*), power source (*i*), and housing market subsector (*h*). The annual value of the aggregate damage, *D*, from emissions from a cohort of newly built units is of a certain housing type, h, and energy source, *i*, given by:

$$D_t = N_{th} \times d_t \times e_i \times E_{ith}$$

where E is the energy consumption of the average household at time *t* living in housing type *h* consuming energy source *i*, *N* is the number of housing units placed in service (built or rehabilitated) of housing type h, *e* is the emission rate of the energy source i, *d* is the social cost per unit of emission at time t. HUD assumes that emission rates do not vary over time but that marginal damage increases over time due to an increasing world population (increasing marginal costs).

The change in damage from a change in technical efficiency is given by

$$\Delta D_t = N_{th} \times d_t \times e_i \times (1 - \alpha) \times \Delta E_{ith}$$

[70] Carbon dioxide equivalents represent a way to measure the volume of CO_2 emissions with the same global warming potential as a given volume of other greenhouse gases.

where α is the rebound factor (the proportion of the technical energy efficiency, or energy savings, that will be consumed). The units are expressed as follows. There are different emission rates for methane (CH_4) and nitrous oxide (N_2O). The present value of the annual stream of contribution to new GHG reductions would continue for the lifetime of the project and would be discounted at a discount rate used to calculate the marginal social cost of GHG.

Figure 33. Units for Calculating Reduction in Damage

Variable	Name	Units	Value
d	Unit cost of emissions (first year)	2020 $/mt CO_2	$51 – $152
ρ	Social discount rate	Rate	0.03
e	Emission rate	mt CO_2/MMBtu	0.045 – 0.093
N	Housing units built	Count	174,700
E	Energy consumption reduction	MMBtu/unit/year	1.0 – 6.0
α	Rebound factor	Percentage	10% – 30%
T	Duration of emissions reduction	Years	10 – 30

Notes: mt = metric ton; CO_2 = Carbon Dioxide; MMBtu = Metric million British thermal units

Damage per Unit: Social Cost of Greenhouse Gases

We estimate the climate benefits of CO_2, N_2O, and CH_4 emissions reductions expected from this proposed rule using the SC-GHG estimates presented in the *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990* published in February 2021 by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG). The SC-GHG is the monetary value of the net harm to society associated with a marginal increase in emissions in a given year, or the benefit of avoiding that increase. The measure of SC-GHG includes the value of climate change damages, including (but not limited to) changes in net agricultural productivity, human health effects, property damage from sea level rise, and increased energy expenditures. The SC-GHG reflects the societal value of reducing emissions of the gas in question by one metric ton. The SC-GHG is the theoretically appropriate value to use in conducting benefit-cost analyses of policies that affect GHG emissions.

The SC-GHG estimates presented in the February 2021 SC-GHG TSD were developed over many years, using a transparent process, peer-reviewed methodologies, the best science available at the time of that process, and input from the public. Specifically, in 2009, an interagency working group (IWG) that included many executive branch agencies and offices was established to ensure that agencies had access to the best available information when quantifying the benefits of reducing CO_2 emissions in benefit-cost analyses. The IWG published SC-CO_2 estimates in 2010 that were developed from an ensemble of three widely cited integrated assessment models (IAMs) that estimate climate damages using highly aggregated representations of climate processes and the global economy combined into a single modeling framework. The three IAMs were run using a common set of input assumptions in each model for future population, economic, and CO_2 emissions growth, as well as equilibrium climate sensitivity. These estimates were updated in 2013 based on new versions of each IAM. In August 2016, the IWG published new estimates of the social cost of methane (SC-CH_4) and nitrous oxide (SC-N_2O) using methodologies that are consistent with the methodology underlying the SC-CO_2 estimates. The modeling approach that extends the IWG SC-CO_2 methodology to non-CO_2 GHGs has undergone multiple stages of peer review.

In February 2021, the IWG recommended the interim use of the most recent SC-GHG estimates developed by the IWG prior to the group being disbanded in 2017, adjusted for inflation. As discussed in the February 2021 TSD, the IWG's selection of these interim estimates reflected the immediate need to have SC-GHG estimates available for agencies to use in regulatory benefit-cost analyses and other applications that were developed using a transparent process, peer reviewed methodologies, and the science available at the time of that process. The February 2021 Technical Support Document also recognized the limitations of the interim estimates and encouraged agencies to use their best judgment in, for example, considering sensitivity analyses using lower discount rates.

The interagency group provides estimates of the present value of damage incurred from carbon for every year between 2020 and 2050. Each year represents the present value of a stream of averted damage from reducing GHGs. Using a 3% discount rate to discount future damages, the cost of one ton of carbon emitted in 2020 is estimated to be $51 (2020$) and climb to $85 per ton by 2050.[71] The Interagency Working Group also presented a "high-impact" scenario representing the upper 95th percentile of simulations run, with costs starting at $152 per ton of carbon emitted in 2020 and rising to $260 by 2050.[72]

Figure 34. Social Cost of Carbon Dioxide Emissions (in 2020 dollars per metric ton of CO_2)

Emissions Year	Discount Rate and Scenario			
	5% average	**3% average**	**2.5% average**	**3% 95th Percentile**
2020	14	51	76	152
2025	17	56	83	169
2030	19	62	89	187
2035	22	67	96	206
2040	25	73	103	225
2045	28	79	110	242
2050	32	85	116	260

Source: Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. (2021). Technical Support Document: Social

[71] See Appendix H. Social Cost of CO_2 Emissions for table of full estimates.

[72] The distribution of the estimates of the social cost of carbon of 2020 emissions discounted at 3 percent is summarized as having a mean of $51 (in 2020 dollars), standard deviation of $92, 25th percentile of $16, 50th percentile (median) of $31, 75th percentile of $54, and to be positively skewed (summary statistics calculated by HUD from IWG estimates across all three IAMs).

Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990.

Figure 35. Social Cost of Methane Emissions (in 2020 dollars per metric ton of CH_4)

Emissions Year	Discount Rate and Scenario			
	5% average	**3% average**	**2.5% average**	**3% 95th Percentile**
2020	666	1485	1953	3906
2025	802	1720	2230	4548
2030	938	1954	2508	5190
2035	1110	2231	2827	5959
2040	1282	2508	3147	6728
2045	1469	2788	3462	7452
2050	1657	3067	3776	8175

Source: https://www.whitehouse.gov/omb/information-regulatory-affairs/regulatory-matters/#scghgs

Figure 36. Social Cost of Nitrous Oxide Emissions (in 2020 dollars per metric ton of N_2O)

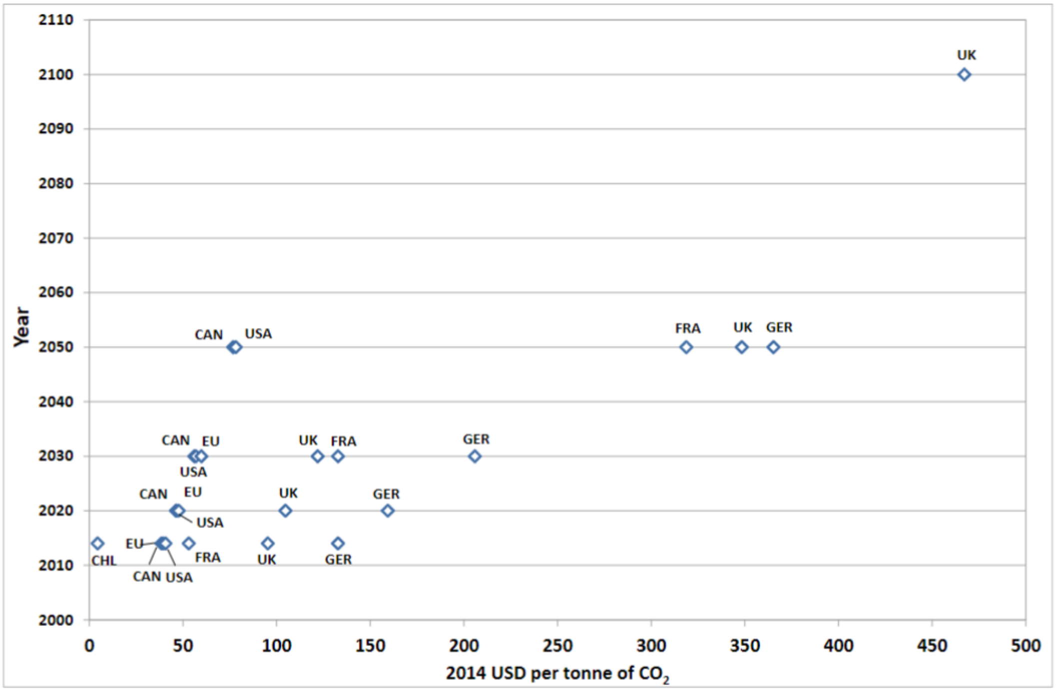
Emissions Year	Discount Rate and Scenario			
	5% average	**3% average**	**2.5% average**	**3% 95th Percentile**
2020	5779	18,405	27,131	48,256
2025	6789	20,591	29,914	54,295
2030	7799	22,776	32,698	60,333
2035	9038	25,236	35,755	67,129
2040	10,276	27,695	38,812	73,924
2045	11,727	30,342	42,033	81,045
2050	13,179	32,989	45,254	88,166

Source: https://www.whitehouse.gov/omb/information-regulatory-affairs/regulatory-matters/#scghgs

Other Social Cost of Carbon Estimates and Considerations

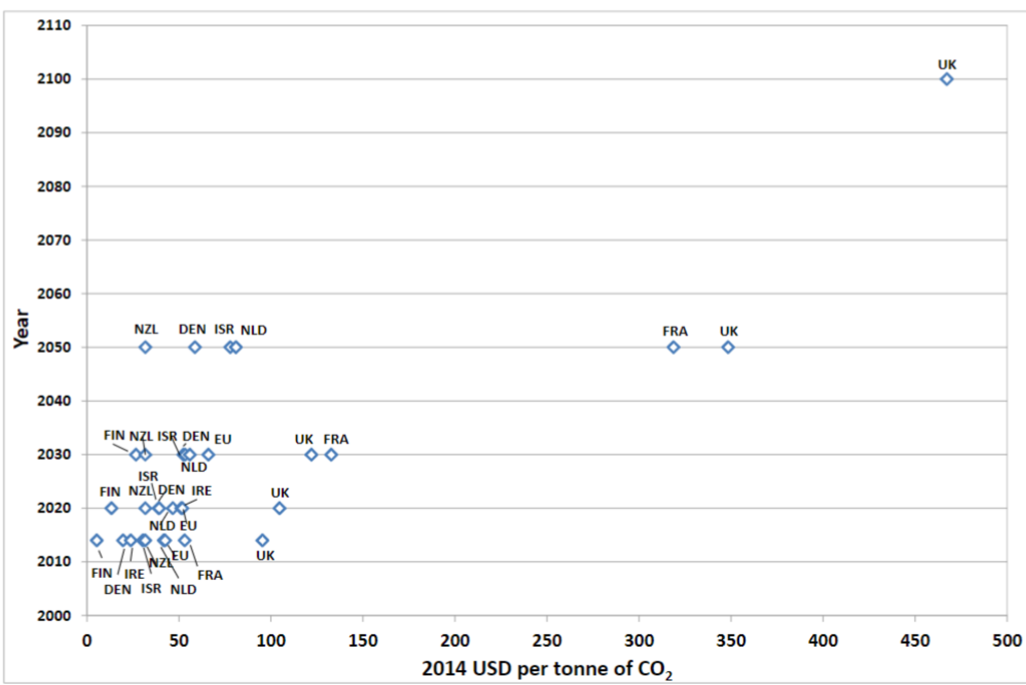
A 2015 survey of OECD countries' use of monetary carbon values in cost-benefit analysis of ex-ante and ex-post transportation and energy policies finds a range of short- and long-term estimates in use (Smith and Braathen, 2015). The estimates used by the United States are on the lower end of the spectrum compared to countries like the United Kingdom, France, and Germany; Canada has made use of the IWG's estimates as a basis for their own analyses. Countries calculate their carbon values in different ways; for investments in transportation, three of 11 respondent countries stated their values are based on estimates of damage costs, while three base them on current policies like the tax rate for petrol in their carbon tax; two use estimates required to reach a particular abatement objective; and one uses projections of future carbon market prices.

Figure 37. Monetary carbon values used in ex ante policy assessments by OECD countries (2014 USD)



Source: Smith and Braathen, 2015

Figure 38. Monetary carbon values used for investment projects in the energy sector by OECD countries (2014 USD)



Source: Smith and Braathen, 2015

The IWG's February 2021 TSD acknowledges a variety of "limitations" that, when "taken together," indicate that the IWG's interim estimates "likely underestimate societal damages from GHG emissions." In particular, "the understanding of discounting approaches suggests discount rates appropriate for intergenerational analysis in the context of climate change that are lower than 3 percent," and the models used to calculate the February 2021 TSD estimates "do not include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature." The IWG's estimates are also limited by "the incomplete treatment of catastrophic and non-catastrophic impacts in the [models]s, their incomplete treatment of adaptation and technological change, the incomplete way in which inter-regional and intersectoral linkages are modeled, [and] uncertainty in the extrapolation of damages to high temperatures." Upon review of the February 2021 TSD and the broader literature, USDA and HUD concur with the IWG's judgment that the social cost of greenhouse gas values used in this analysis may be underestimates, though they remain appropriate estimates to use at this time. As the February 2021 TSD acknowledges, more complete treatment of such considerations, as well as incorporation of environmental justice and intergenerational equity considerations, could justify increased SCC estimates in the future (IWG 2021; *see also* Dietz, et al., 2021; Erickson, et al., 2021; Johnson and Hope, 2012). Other recent estimates in the literature show that when the damage functions and discount rates are updated to be consistent with the latest available economics and science, estimates of the SCC may be considerably higher than the IWG (2021) estimates.

The Environmental Protection Agency (EPA) has newly developed estimates of the social cost of greenhouse gases, which they use as a sensitivity analysis to the IWG's SC-GHG estimates in their regulatory impact analysis of a proposed rule on performance standards for the oil and natural gas sector. These estimates were published in November 2022 in Appendix B of the RIA (of the Supplemental Proposal for the Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review) and an accompanying technical report (Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances), which is undergoing external peer review. These estimates are also subject to public comment, including a multi-day public hearing process.

The EPA's estimates are higher than the 2021 IWG's estimates. For example, for emissions occurring in 2035, the EPA's SC-CH_4 values range from $2,300 to $3,600 per metric ton of CH_4 (in 2019 dollars), whereas the IWG's average SC-CH_4 values range from $1,100 to $2,800 per metric ton of CH_4 (in 2019 dollars). The EPA's estimates are based on a number of changes responding to the 2017 National Academies report reviewing the IWG's SC-CO_2 estimates, including three new damage functions. As the EPA's new SC-GHG estimates have not yet been published in a final rule, completed peer review, or been adopted by the Interagency Working Group, HUD and USDA do not use them at this time.

Discount Rate

The choice of the discount rate is of particular importance when analyzing climate change, given the unusually lengthy duration of its impacts (Nordhaus, 2007; Stern, 2007; Varian, 2008). The benefits of reducing greenhouse gases emissions are often estimated to be intergenerational. Thus, the discount rate can be the most important variable in determining whether the present value of future benefits outweighs the costs of reduced current consumption. In computing their estimates of damage, the Interagency Working Group used discount rates of 2.5, 3, and 5 percent, and presented two scenarios at the 3 percent discount rate. The IWG determined that focusing on discount rates that are meant to approximate the consumption discount rate—i.e., that are lower than OMB Circular A-4's default 7 percent rate—is appropriate given that damage estimates developed for use in the SC-GHG were estimated in consumption-equivalent terms. Accordingly, consistent with the National Academies (2017), application of OMB Circular A-4's guidance for regulatory analysis would imply use of the consumption discount rate to calculate the SC-GHG. Consistent with those determinations, HUD and USDA focus on the estimates calculated with a 3 percent rate, while presenting a broader range of values, as in Figure 32 above.

However, a 3 percent discount rate may produce more conservative estimates of benefits than typically found in the environmental economics literature. The current scientific and economic understanding of discounting approaches suggests discount rates appropriate for intergenerational analysis in the context of climate change are likely to be less than 3 percent, near 2 percent or lower (IWG, 2021).

Emission Rate

The emission rate of metric tons of greenhouse gases produced per BTU consumed varies by power source. The primary source for these data is the U.S. Energy Information Administration. The most direct method of calculating the CO_2 emission rate for the residential sector is to divide total reported CO_2 emissions from energy consumption in the residential sector (0.9 billion metric tons[73]) by the corresponding residential energy consumption (20,065 trillion BTUs[74]), which includes natural gas, petroleum, retail electricity, and electrical system energy losses.[75] The average emission factor, or emission coefficient, would be 45 kg CO_2/MMBtu.

Alternatively, a weighted average can be taken of the emission coefficients for each power source used for residential energy. There are several energy sources missing from the basic calculation: all renewable energy sources[76] and electrical system energy losses.[77] The emission rates for natural gas and petroleum[78] are those for the residential and commercial sectors as provided by EIA (EIA, 2021).[79] Carbon dioxide emission coefficients from the generation of electricity are taken from the Environmental Protection Agency's GHG Emission Factors Hub (EPA, 2021). HUD includes both direct (sales) and indirect (energy losses) emissions, using an emission factor of 109 kilograms of CO_2 per million BTUs for both. HUD finds that the weighted average CO_2 equivalent emission factor is 93.9

[73] U.S. Energy Information Administration. Brett Marohl. July 26, 2021. "In 2020, the United States produced the least CO2 emissions from energy in nearly 40 years." https://web.archive.org/web/20211115180339/https://www.eia.gov/todayinenergy/detail.php?id=48856

[74] U.S. Energy Information Administration. Table 2.2 Residential Sector Energy Consumption. Monthly Energy Review February 2022. https://web.archive.org/web/20220302022330/https://www.eia.gov/totalenergy/data/monthly/pdf/sec2_5.pdf.

[75] Electrical system energy losses represent energy lost in the distribution of electrical power. It is calculated as the primary energy consumed by the electric power sector minus the energy content of electricity retail sales.

[76] Renewable energy sources include geothermal, solar/photovoltaic and biomass and account for 7 percent of energy consumption (total primary energy consumption plus electricity retail). Generally, renewable sources are excluded from CO_2 emission estimates either because the emissions are assumed to be zero or because the estimate is unreliable, and the share is too small to warrant the inclusion of an imprecise estimate. The current convention is to exclude biomass-related emissions from the reporting of total energy-related emissions (U.S. EIA 2012). There is considerable controversy surrounding the impact of biomass energy on climate change. Some argue that the CO_2 emission factor is effectively zero because parts of the biomass crop, which are not harvested (roots and trunks), form a CO_2 sink compensating for the CO_2 emissions from energy production. Others argue that biomass is a "dirtier" energy source than coal because wood is a less efficient fuel. There are also concerns that there would be widespread harvesting of trees. Resolving these issues would require sophisticated modeling techniques. Some imprecision from excluding this power source is not grave because biomass represents less than 4 percent of total residential consumption. HUD assumes that the emission rate of solar photovoltaic energy is equal to zero. Such an assumption is not completely correct because, although the carbon emissions from operation are close to zero, the emissions due to manufacturing are such that the average cost is positive (Alsema, 2003). However, we do not consider the embedded costs for other sources of power. The emission rate of geothermal energy is assumed to be zero. Energy is required to operate a heat pump. The emissions resulting from energy required for operation of the heat pump are classified under the appropriate energy source.

[77] Energy is consumed in the production, distribution, and transmission of electricity. Losses are assigned to each sector (residential, commercial, transportation, and industrial) in proportion to each sector's electricity retail sales. Electricity losses for the residential sector are 9,275 trillion BTUs, almost twice that of retail sales. Including an emission estimate for energy losses will change the average estimate.

[78] The emission coefficient for petroleum was calculated as an average of the emission coefficients for propane, diesel, and home heating fuel (distillate fuel oil), kerosene, and gasoline.

[79] https://www.eia.gov/electricity/state/unitedstates/

kilograms of CO_2e/MMBtu by weighting the emission coefficient factors by the share of residential energy consumption from each power source. Given that both approaches are credible but arrive at a different estimate, HUD uses a range of emission factors from 0.045 to 0.094 mt CO_2/MMBtu.

Figure 39. Greenhouse Gas Emission Coefficients

Power Source	**Residential Consumption**		**Emission Rate, CO_2**	**Emission Rate, CH_4**	**Emission Rate, N_2O**	**Emission Rate, CO_2 Equivalent**[80]
	Consumption (trillion BTU)	Consumption (percent share)	kg CO_2/ MMBtu*	gram CH_4/MMBtu	gram N_2O/ MMBtu	kg CO_2e/ MMBtu
Natural Gas	4,818	42	52.91	1.0	0.10	52.96
Petroleum[81]	984	8	70.07	3.0	0.60	70.32
Renewables[82]	788	7	–	–	–	–
Electricity (sales)	4,988	43	108.78	8.6	1.2	109.36[83]
Electricity (losses)	9,275	–	108.78	8.6	1.2	109.36
Total	**20,853**	**–**	**93.47** (weighted)	**6.5** (weighted)	**0.90** (weighted)	**93.90** (weighted)

*Kilograms of carbon dioxide emissions per million BTUs consumed

Primary sources:

- CO_2 emission rates for natural gas and petroleum: https://web.archive.org/web/20220302015840/https://www.eia.gov/environment/emissions/co2_vol_mass.php
- CH_4 and N_2O emission rates for natural gas and petroleum: https://web.archive.org/web/20211105081913/https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_apr2021.pdf
- Emission rates for electricity (total output emission rates converted to g/MMBtu from lb/MWh): https://www.epa.gov/system/files/documents/2022-01/egrid2020_summary_tables.pdf
- Consumption: https://web.archive.org/web/20220302022330/https://www.eia.gov/totalenergy/data/monthly/pdf/sec2_5.pdf

Units Built

Approximately 170,000 units in total are expected to be affected by the Notice, including 150,000 units for the IECC 2021 requirement (about 124,000 single-family units and 27,000 low-rise multifamily units) and approximately 16,000 mid- and high-rise multi-family units for the ASHRAE 90.1 2019 requirements. Figures A1 and A2 in Appendix A provide a programmatic and geographic breakdown of these units.

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[80] Emission rates of other greenhouse gases are converted to CO_2 equivalent, or CO_2e, by multiplying their emission rate by their global warming potential (GWP). The 100-year GWP used for CH_4 is 25 and for N_2O is 298. Source: Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (AR4), 2007.

[81] Petroleum includes heating oil, kerosene, and liquefied petroleum gas (LPG), which is mostly propane. See https://www.eia.gov/energyexplained/use-of-energy/homes.php. As an approximation, the individual emission factors for each fuel are averaged to get the emission rate for petroleum.

[82] Renewable energy sources include geothermal energy, solar energy, and wood fuels.

[83] Table 6 Electricity, EPA Emission Factors for Greenhouse Gas Inventories. Converted from 822.6 lb/MWh CO2 equivalents. See https://web.archive.org/web/20211105081913/https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_apr2021.pdf or https://web.archive.org/web/20220127232211/https://www.epa.gov/system/files/documents/2022-01/egrid2020_summary_tables.pdf.

Change in Household Energy Consumption

DOE estimates that, for a weighted average of single-family and low-rise multifamily housing across all 50 states and the District of Columbia, the 2021 IECC saves 8.79 percent source energy use intensity (EUI) over the 2018 IECC.[84] By structure type, the source energy use intensity savings are estimated to be 8.1 percent on average for single-family units and 11.2 percent for low-rise multifamily units. For ASHRAE, DOE estimates that adopting ASHRAE 90.1-2019 in mid- or high-rise multifamily buildings would yield average site energy savings of 2.65 percent over the 2016 edition, and average energy cost savings (Energy Cost Index (ECI)) of 2.5 percent.[85,86,87]

Energy consumption and reduction for housing subject to the 2021 IECC or ASHRAE 90.1-2019 can be estimated using the Residential Energy Consumption Survey (RECS) conducted by the U.S. Energy Information Administration. RECS estimates energy consumption by factors including household income.[88]

According to RECS, renter households living in apartments consume on average 38.7 MMBtu per year. An estimated 2.7 percent reduction in energy use between the 2016 and 2019 ASHRAE 90.1, without any rebound effect, would yield average energy savings of 1.04 MMBtu per household.

According to RECS, households with an annual household income between $40,000 and $59,999 in 2015 were estimated to consume 73.6 MMBtu on average. Households with FHA-insured forward mortgages had a median household income around $54,000 in 2016. An estimated 8.1 percent reduction in energy use between the 2018 and 2021 IECC, without rebound effects, would be equivalent to energy savings of 6.0 MMBtu per household in a single-family unit. Using the previous estimate of renter consumption and an 11.2 percent reduction in energy use yields average energy savings of 4.3 MMBtu per household in a low-rise multifamily unit.

Put together, the expected aggregate savings without rebound effects are estimated to be about 900,000 MMBtu across approximately 170,000 units of HUD- or USDA-assisted housing stock subject to new IECC or ASHRAE standards.

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[84] While PNNL reports site energy savings, source energy savings, and energy cost savings, the EPA recommends using source energy savings to provide a complete picture of energy efficiency, by taking all energy use, including transmission, delivery, and production losses, into account. See https://www.energystar.gov/buildings/benchmark/understand_metrics/source_site_difference.

[85] *Op cit.,* PNNL *Energy Savings Analysis*, July 2021

[86] PNNL, Impacts *of Model Building Energy Codes – Interim Update*, July 21, 2021. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-31437.pdf. For all commercial buildings, DOE estimates national site energy savings of 4.7 percent and energy cost savings of approximately 4.3 percent.

[87] DOE, Federal Register Notice, https://www.federalregister.gov/documents/2021/07/28/2021-15971/final-determination-regarding-energy-efficiency-improvements-in-ansiashraeies-standard-901-2019

[88] RECS was last administered in 2015 and 2020. As of this draft, 2020 survey data on energy usage was not available.

Figure 40. Technical Efficiency in Energy Consumption (Millions of BTUs per Year)

Code	Number of Housing Units	Energy Savings Per Unit (MMBtu)	Total Energy Savings (MMBtu)
ASHRAE – mid- or high-rise multifamily	16,000	1.04	17,000
IECC – single-family	124,000	5.98	740,000
IECC – low-rise multifamily	27,000	4.34	120,000
Total	166,000	5.24	870,000

Note: Totals may not add up due to rounding.

Rebound Effect

Whatever the predicted technical efficiencies of an energy efficiency upgrade, the actual energy consumption reduction of a household is likely to be smaller due to a behavioral response known as the "rebound effect." An energy-efficient investment effectively lowers the price of energy to produce heating, cooling, and lighting. Lowering the cost of energy will lead to both income and substitution effects, raising the demand for energy as long as the outputs from energy consumption are normal goods. By increasing energy efficiency, the upgrade reduces the expense of physical comfort and thus would increase the demand for comfort. The decision to invest in energy efficiency could be driven as much by the desire to consume more heating in the winter or cooling in the summer as by an explicit consideration of the savings.

The direct rebound effect accounts for the change in behavior from a change in energy efficiency and is expressed as a percentage of the expected energy savings from a change in technical efficiency.[89] For example, a 10 percent rebound factor indicates that 90 percent of the engineering estimate of energy savings would be realized. Although it is difficult to pinpoint a precise proportion, the measured rebound effect of residential energy use is almost always less than 50 percent (Clinch and Healy, 2001). A highly cited review article of empirical estimates of the direct rebound effect from 2009 concludes that for household energy consumption in OECD countries, the direct rebound effect is generally less than 30 percent (Sorrell, Dimitropoulos, and Sommerville, 2009).

Most empirical studies examine the direct rebound effect, which measures the consumer's change in energy consumption for a specific end-use from a change in energy efficiency of that specific end-use (e.g., heating, cooling, appliances, and lighting). Sorrell (2007) and Greening, et al. (2000) review many studies and find estimates for space heating from 2 to 60 percent, with a central tendency between 10 and 30 percent. Sorrell (2007) suggests that 30 percent would be a reasonable rebound effect for space effects. One reason for accepting this slightly higher estimate is that the rebound effect can be expected to vary by income (Clinch and Healy, 2001): the rebound effect will be larger when energy consumption is a larger proportion of the budget. Thus, HUD expects that low-income households residing in HUD buildings will be characterized by higher rebound effects. The estimate of 30 percent is also within the range for other types of residential energy consumption such as space cooling, appliances, and water heating.

[89] This discussion focuses on the "direct" rebound effect caused by behavioral responses to energy efficiency. There may also be a significant "indirect" effect arising from economy-wide energy consumption as households spend their energy savings on other goods. An additional but very minor rebound effect may be the one-time cost necessary to supply energy-efficient technology ("embodied energy"). The indirect rebound effects are not currently estimated with any degree of reliability.

The long-run rebound effect is usually assumed to be greater than the short-run rebound effect (immediate response). Over the long run, a consumer will become more aware of the energy efficiency improvement and adapt their lifestyle to the efficiency by changing habits. In addition, long-run effects may also include physical changes in equipment. For example, with a better water heater, a household might purchase a larger washing machine that uses more hot water. For the purpose of this analysis, we use the long-run direct rebound effects reported by Sorrell (2007).[90]

Figure 41. Ranges of Estimates for Long-Run Direct Rebound Effects from Previous Studies*

Energy service	Range of estimates (%)	Best guess	Number of studies
Residential lighting	5 – 12	5-12	4
Space heating	2 –60	10-30	9
Space cooling	0 – 50	1-26	9
Water heating	<10 – 40	—	5
Other consumer energy services	0 – 49	<20	3

*Table adapted from Sorrell (2007) and IRGC (2013).
Sources: Water heating from Jenkins et al. (2011). Space heating and other consumer energy services from Sorrell (2007). Residential lighting and space cooling from Greening, et al. (2000).

Gillingham, et al. (2013) argue that while higher rebound effects such as 30 percent may seem reasonable based on empirical studies of energy demand behavior, the response to energy efficiency is probably lower and closer to 10 percent. Many of the higher estimates of the rebound effect are long-run rebound effects, which are difficult to estimate, because, over time, there are other confounding factors to account for. To account for the wide range of estimates and the uncertainty surrounding, HUD assumes a range between 10 and 30 percent.

The size of the rebound effect does not reduce the benefit to a consumer of energy efficiency but informs us how these benefits are allocated between reduced energy costs and increased comfort. For example, Boardman (1994) estimates that 70 percent of the benefits of energy-efficient improvements result in energy savings, while 30 percent go toward increased health and comfort. However, the rebound effect has implications for measuring the *public* benefit of reducing energy consumption. If one of the goals of an energy efficiency investment program is to reduce emissions, then understanding the impact on energy consumption is critical to evaluating energy efficiency policy.

Taking account of the rebound effect, the technical efficiency provided by the energy standards produces a reduction in energy consumption of 631,000 to 811,000 MMBtu from a technical efficiency of approximately 900,000 MMBtu.

Total Benefits from Reducing Greenhouse Gas Emissions

The tables below summarize the aggregate social benefits from reducing carbon emissions for different marginal social cost scenarios (average and worst case), lifecycles, and scenario assumptions. The average annualized value of the social benefits of reducing greenhouse gas emissions (including carbon dioxide, methane, and nitrous oxide), discounted at 3 percent, ranges from $1.6 million to $15.3 million. The corresponding present value of benefits over 30 years range from $14 million to $308 million.

[90] For a discussion of the microeconomics of the rebound effect, see Chan and Gillingham (2015).

Figure 42. Annualized Value of Reduction in CO_2 Emissions over All Units ($2021 Millions)

Lifecycle (Years)	Emission Factor of 45 kg/MMBtu				Emission Factor of 93 kg/MMBtu			
	Rebound of 30%		Rebound of 10%		Rebound of 30%		Rebound of 10%	
	Average	High	Average	High	Average	High	Average	High
10	1.6	4.9	2.1	6.2	3.4	10.1	4.3	13.0
20	1.8	5.3	2.3	6.8	3.6	11.0	4.7	14.2
30	1.9	5.7	2.4	7.3	3.9	11.8	5.0	15.2

Note: Average and high estimates correspond to marginal social costs of greenhouse gases under discount rates of 3% at the median scenario and the 95th percentile scenario, respectively.

Figure 43. Average Annualized Value of Reduction in CH_4 Emissions over All Units ($2021 Thousands)

Lifecycle (Years)	Emission Factor of 6.5 grams/MMBtu			
	Rebound Factor of 30%		Rebound Factor of 10%	
	Average	High	Average	High
10	7.2	19.1	9.3	24.5
20	8.1	21.5	10.4	27.7
30	8.9	23.8	11.5	30.6

Figure 44. Average Annualized Value of Reduction in N_2O Emissions over All Units ($2021 Thousands)

Lifecycle (Years)	Emission Factor of 0.9 grams/MMBtu			
	Rebound Factor of 30%		Rebound Factor of 10%	
	Average	High	Average	High
10	11.8	31.3	15.2	40.2
20	13.0	34.4	16.7	44.2
30	14.0	37.3	18.0	47.9

Figure 45. Annualized Value of Reduction in CO_2, CH_4, and N_2O Emissions over All Units ($2021 Millions)

Lifecycle (Years)	Emission Factor (low)				Emission Factor (high)			
	Rebound of 30%		Rebound of 10%		Rebound of 30%		Rebound of 10%	
	Average	High	Average	High	Average	High	Average	High
10	1.6	4.9	2.1	6.3	3.4	10.1	4.3	13.0
20	1.8	5.4	2.3	6.9	3.7	11.1	4.7	14.2
30	1.9	5.7	2.4	7.4	3.9	11.9	5.0	15.3

Global versus Domestic Benefits

In this RIA, we use estimates of the global damages of GHG emissions to monetize the benefits of reducing GHG emissions. An alternative could have been to use an estimate of the benefit of GHG emission abatement limited to the U.S. population. One could argue that a simple domestic estimate could be derived by pro-rating the global damage estimate by a nation's share of the global population, GDP, energy use, or some other appropriate share. However, we did not attempt to partition the global damages from GHG emissions for many reasons.

Climate science informs us that emissions are a global externality. One ton of GHG imposes damages largely independent of the national origin.[91] A central insight of economics is that whenever an actor (one nation) can benefit from others' efforts (reduction of emissions) without bearing the costs (emission abatement), then there will be a strong tendency to misallocate resources (oversupply of emissions or undersupply of abatement). Even basic estimates of the difference between global and domestic social cost benefit illustrate the misalignment of incentives. Older estimates by the IWG of the U.S. share of the global cost ranged from 7 to 23 percent. [92] The U.S. would enjoy only a small portion of the benefits from reducing its own emissions, and at the same time bear the costs of other nations' emissions. Other nations would face similar incentives. [93] In a noncooperative situation, in which the policy objective of every nation is their own domestic social cost of GHG, Nordhaus (2015) estimates that damages from GHG emissions would be severely undervalued (11 percent of actual damages). A domestic measure limits climate policy to suboptimal outcomes. The global measure is therefore more useful for climate policy and more appropriate when there are cooperative international agreements.

Assessing the benefits of U.S. GHG mitigation activities requires consideration of how those actions may affect mitigation activities by other countries, as those international mitigation actions will provide a benefit to U.S. citizens and residents by mitigating climate impacts that affect U.S. citizens and residents. A wide range of scientific and economic experts have emphasized the issue of reciprocity as support for considering global damages of GHG emissions. [94] In order to achieve an efficient allocation of resources for emissions reduction on a global basis—and so benefit the U.S. and its citizens—it is necessary that all countries base their policies on a global estimate of damage.[95]

In addition, the IWG (2021) concluded that approximations of domestic damages fail to capture many climate impacts that can affect the welfare of U.S. citizens and residents. Examples of affected interests include direct effects on U.S. citizens and assets located abroad, international trade, and tourism, and spillover pathways such as economic and political destabilization and global migration that can lead to

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[91] Accordingly, the IWAG estimates simulate the interaction between global climate trends and economic activity. One of the three models, DICE, is global and the other two (FUND and PAGE) develop damage estimates at a transnational regional level. For a description of the different IAMS and discussion of the difficulties in separating the global damage estimates by nation or region, see the National Academies of Sciences (2017).

[92] The National Academies of Sciences (2017) presents the initial estimates by IWG (in 2010) of estimating the US share of the cost of carbon. The U.S. share ranged from 7 percent and 23 percent. Despite these estimates, the IWG concluded that the appropriate measure for use in policy analysis is the global cost.

[93] For estimates of regional SCC for large nations and regions, see Nordhaus (2017).

[94] When there is reciprocity among nations in climate agreements, then nations will find it advantageous to adopt a target greater than a strict domestic cost of GHG. Kotchen (2018) concludes that "… if a country expects a decrease in its own emissions to decrease that of all others in proportion to the ratio of its external cost of emissions to its internal costs, then it is individually rational for the country to internalize the GSCC [Global Social Cost of Carbon]." If there are repeated negotiations, then the optimal strategy of all nations would be to adopt a measure of damages above the domestic social cost, and for some nations, above the global social cost.

[95] See, for example, Weitzman (2014), who concludes that the market failure can be resolved only if different nations can agree upon a global minimum price of emissions. See Stern (2007) for discussions of implementing a single price of GHG. See Nordhaus (2015) for a discussion of the conditions for international climate agreements to reduce free riding.

adverse impacts on U.S. national security, public health, and humanitarian concerns. The IWG found that those impacts are better captured as an additional portion of the global measure of the social cost of greenhouse gases.

Using the global social cost of greenhouse gases developed by the IWG, as opposed to approximating an estimate of the domestic cost of greenhouse gases, does not affect the direction of the economic impact of this regulatory action. Similarly, using higher or lower SC-GHG estimates also does not affect the conclusion of the analysis. The majority of the benefits of the adoption of the 2021 IECC and the 2019 ASHRAE 90.1 come from the energy savings associated with the energy efficiency gains of these codes. Finally, there are no obvious international costs or transfers from this regulatory action that we have omitted from the RIA.

Benefits: Health and Safety

Lower-income households have higher energy burdens on average as compared to higher-income households. A recent study estimates the energy cost burden to be 7 percent on average for low-income households and 2 percent on average for higher-income households (Kontokosta, Reina, and Bonczak, 2020). Within the same income band, households of color experience higher average energy cost burdens than households headed by white householders. Energy burdens are also higher in the South and in rural areas (Brown, et al., 2020). Households with high energy burdens are sometimes forced into making a tradeoff between using energy and fulfilling other basic needs; this can trigger mental health impacts like anxiety and depression (Hernández, 2016). Households with higher energy cost burdens are more likely to report issues like food insecurity and housing instability (Hernández and Bird, 2010).

Low-income households with high energy burdens who do not reduce or maintain their energy consumption as a result of increased energy efficiency, but instead use these energy savings to increase their energy consumption (as detailed in the previous section on the rebound factor), could see benefits from increased health and safety. Benefits could come in the form of avoidance of fire from improper use of alternative heating sources; reduced hypothermia during cold weather; and reduced heat exhaustion, stroke, or dehydration during warm weather (Megdal and Piper, 1994). Greater energy efficiency allows households to afford energy for heating during severe cold or cooling during extreme heat. Doing so reduces the risk of both death and illness for lower-income populations with health vulnerabilities, including children and older adults.

Additionally, there is much documented literature on the disproportionate siting of power plants and other polluting infrastructure near lower-income communities and communities of color. For instance, exposure to fine particulate matter (PM2.5), which is associated with increased risk of death and health problems, is higher for Black individuals and low-income individuals (Thind et al., 2019). Increasing energy efficiency and reducing the emissions of greenhouse gases will have disproportionate health, safety, and quality-of-life benefits for lower-income communities and communities of color situated near power plants, oil wells, hydraulic fracturing sites, and other fossil fuel infrastructure.

Unintended Health Consequences

A potential unintended consequence of adopting stricter energy efficiency codes could be to increase the presence of mold or radon. exposure to mold or radon. A tighter building envelope would, in certain climates, lead to greater moisture and foster mold. Mold can damage the unit and cause health problems for individuals with allergies to mold. This would impose the additional costs of mold remediation to limit adverse impacts on the unit and occupants. However, homes with well-sealed basement floor slabs and walls and radon venting reduce radon exposure. Homes with mechanical ventilation also mitigate mold exposure (Shrestha et al., 2019). New construction built to unadulterated new energy efficiency codes would have the necessary venting requirements for mitigating condensation and humidity that can lead to mold and other indoor air quality issues. Mold exposure is more of an issue in older buildings undergoing energy retrofits, to which this notice does not apply.

An increased exposure to radon is another potential adverse impact from tighter building envelopes. Radon is a radioactive gas emitted by soil and rocks. Breathing higher levels over an extended period of time can lead to a higher risk of lung cancer. The effect of energy efficiency measures on radon levels is not obvious: sealing the foundation can inhibit entry of radon gas but sealing walls and ceiling could trap radon. Any increase in radon levels would depend upon pre-existing conditions. Exposure to radon would depend upon whether residents occupied the areas where radon was present over an extended period. A study by Oak Ridge Laboratories (Tonn et al., 2015) found that radon levels increased by a small amount after weatherization but was not able to make any conclusions concerning exposure to radon.

Impact on the Availability of Affordable Housing

EISA requires that HUD-USDA explore the possibility of adverse effects from the implementation of a stricter energy code on the "affordability" and "availability" of covered housing units.[96] For the analysis of the update to the 2009 IECC and ASHRAE 90.1-2007 published in 2015, HUD defined affordability as "a measure of whether a home built to the updated energy code is affordable to potential homebuyers or renters," while the availability of housing was defined as a measure "associated with whether builders will make such housing available to consumers at the higher code level; i.e., whether the higher cost per unit as a result of complying with the revised code will impact whether that unit is likely to be built or not." HUD concluded that "[t]hough both higher construction costs and hedonic increases in demand for more energy-efficient housing are expected to contribute to an increase in housing prices or contract rents, HUD and USDA do not project such higher prices to decrease the quantity of affordable housing exchanged in the market."

The current proposed update of IECC and ASHRAE requirements constitutes a more expansive impact. The per-unit cost is greater than for the previous update. For example, PNNL's estimate of the upfront incremental cost of building to the IECC 2021 from the IECC 2009 is approximately $5,500, ranging from a low upfront incremental cost of $2,800 in Climate Zone 1 to a high of $6,800 in Climate Zone 8 (see Figure 11). The geographic scope of the impact of the proposed update is also more extensive. In 2015, construction in only 16 states was affected. For the proposed update, 47 states and the District of Columbia are below the 2021 IECC. On the order of 100,000 newly built units would have to comply with the IECC 2021 standard, compared to approximately 10,000 annually for the 2015 Notice. The more stringent update merits a more detailed discussion of the potential impacts on the availability of housing to program participants, as well as the housing market overall. But having completed a more extensive analysis, our conclusion of little to no impact on availability remains the same.

This availability analysis focuses primarily on FHA-insured purchases of newly built homes. There are multiple reasons for concentrating on single-family housing. First, FHA-insured single-family purchases

[96] EISA does not provide a formal measure of housing affordability and availability.

represent the majority of units affected by this Notice. Second, homebuyers and builders of single-family homes will probably be more sensitive to the IECC requirement than renters and builders affected by the ASHRAE update because of the higher cost. The estimated incremental cost for single-family homes is greater than for multifamily IECC and ASHRAE.

The Impact of an External Per Unit Cost on Market Equilibrium

Public economics provides a conceptual framework for estimating the incidence of an excise tax on the price paid by consumers, the price received by producers, and the quantity of a good exchanged on the market.[97] If the change in cost is small, then the tax incidence approach offers some useful insights and allows us to develop a rough estimate of the impact based on readily available economic measures.

The change in market quantity depends not only on the decisions of builders and the real estate industry more broadly, but also on the willingness of buyers to absorb a price change. The impact on availability, as measured by the quantity of housing, would be given by:

$$\frac{\Delta Q}{\mathrm{Q}} = \left(\frac{E_S \cdot E_D}{E_S - E_D}\right) \cdot \left(\frac{\Delta C}{P}\right)$$

The percentage change in the quantity of housing, ΔQ/Q, depends on the price elasticity of demand E_D (the percentage change in quantity demanded from a percentage change in price), the price elasticity of supply E_S, and the incremental cost ΔC, as a fraction of the pre-regulation sales price P.[98] The percentage reduction of quantity is greater as demand and supply are more responsive to price changes (or more price-elastic) and as the incremental cost constitutes a larger portion of the sales price before the introduction of the cost.[99]

Estimates of the price elasticities of demand and supply for housing vary due to differences in empirical methods, data sets, and geographies and time periods examined. Generally, the estimate of the price elasticity of demand is less than -1, and as low as -0.2 for low-income households, but has also been estimated to be greater (in absolute value) than -1. A range between -0.5 and -1.25 covers most estimates (Dacquisto and Rodda, 2006).[100] Generally, lower-income households have a lower measured price elasticity of demand for housing (Zabel, 2004), meaning they are less sensitive to price changes, likely due to the lack of housing options. The positive association between income and the absolute value of price elasticity stems from shelter being a necessary good.[101]

The price elasticity of supply has been estimated at a wide variety of levels for different housing markets, primarily due to differences in the ease of building additional units.[102] Consistent with factors that vary locally, statistically significant estimates of the price elasticity of housing supply for an entire

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[97] An excise tax creates a gap between the price paid by consumers and received by producers.

[98] See Appendix E for the development of this calculation.

[99] The pass-through rate is the proportion of the cost paid by buyers, which is higher as demand is less price-elastic and supply is more price-elastic.

[100] A value of -1 implies that for every percentage point increase in the price of housing, there is a one percentage point decrease in the quantity demanded.

[101] Mayo (1981) shows this to be the case when a household must consume a minimum amount of housing (a Stone-Geary utility function).

[102] Gyourko and Saiz (2006) attribute the local variation in construction activity to more than the cost of materials but also to local wages, local topography, and the local regulatory environment.

metropolitan area range from 1.5 to 22 (Green et al., 2005). Dacquisto and Rodda (2006) suggest 3.0 as a central estimate of the price elasticity of supply of housing for regulatory analysis.[103]

For the chosen values of price elasticity (a price elasticity of demand of -1 and a price elasticity of supply of 3), the percentage decline in new construction covered by this Notice would be -0.75 multiplied by the proportional cost increase. The incremental cost is expected to be approximately 2 percent of the pre-regulation sales price (a $5,000 incremental cost and average $250,000 sales price). Our first estimate from this analysis is that the quantity in an affected submarket would decline by 1.5 percent of the pre-notice market activity.

The estimate of a -1.5 percent reduction of quantity is not firm. Both demand and supply are more elastic in the long run than in the short run. The elasticities of supply and demand will be higher for the affected submarket than for the overall housing market because the regulation does not directly affect the entire housing market, only households supported by the programs specified in this Notice. The regulatory action will also have an impact on the quality of housing supplied. Including the benefits imparted by the Notice would diminish, and maybe even reverse, the contraction of new construction from higher minimum standards.

For our discussion of availability, we use the sales of new construction as the measure of housing quantity rather than the entire stock.[104] Sales is an appropriate measure of availability to those seeking to purchase or rent a home. For FHA-insured borrowers, the share of new home sales is similar to the national average and has varied from 10 to 15 percent of all FHA single-family purchase loans. Because newly built units constitute 10 to 15 percent of all FHA sales, the negative impact on quantity translates to a mere 0.15 to 0.25 percent reduction of FHA purchase loans.

New Construction, Housing Supply, and Availability

Most housing units are already built. The median owner-occupied home in the U.S. was built in 1979 (American Housing Survey, 2019) . In the short run, the supply of housing is very price inelastic. The only way for the real estate industry to respond to price changes is to either abandon units in response to declining prices or offer existing units for sale in response to increasing prices. But in the short run, the stock of housing does not change. Intermediate supply decisions consist of upgrading, repairing, and maintaining housing in response to increasing prices or to let housing depreciate in response to declining prices. In the longer run, new construction expands the housing stock, replaces losses to the housing, and provides vacant units for sale.[105,106] Newly built units represent only 1 to 2 percent of the entire housing stock in any year but are a much larger proportion of housing sales, approximately 10

[103] For every percentage point increase in the price of housing, the quantity supplied increases by 3 percentage points.
[104] We did not use a stock-flow model of the market for this analysis. The ones that are more manageable do not account for differences in quality of housing units and for a variety of submarkets.
[105] The price elasticity of supply can be separated into different components such as the occupancy elasticity, repair elasticity, and inventory elasticity (Rydell, 1982).
[106] The economic incentives to build when prices are increasing are greater than the incentives to demolish when prices are decreasing (Glaeser and Gyourko, 2005).

percent. New construction and redevelopment also play an important role in improving the quality of the housing stock.[107]

Construction activity is volatile and so will respond to changes in prices and costs.[108] A builder's choice of whether to build at the IECC 2021 standard will affect the availability of newly built units that are marketable to FHA-insured homebuyers. If builders predict that their costs outweigh their expected private benefits of building to the IECC 2021 standard, then the supply of newly built homes for FHA-financed borrowers could contract substantially.[109] FHA-insured borrowers would still be able to find housing, but the opportunities could be restricted if builders avoided compliance costs by building to a lower state-level standard. Endogenous to the choice to build to the IECC 2021 standard will be when and how to build. For developers who have not yet purchased land, the decision of where to build could also be affected.

Preserving FHA-insured borrowers as potential customers would be one of the benefits of building to the IECC 2021 standard. The chances of selling a home quickly, and thus avoiding the cost of delay, is greater when there are more entrants to the market. Thus, a seller may be willing to make price concessions or bear additional costs in order to hasten the sale (DiPasquale and Wheaton, 1996).[110] Depending on the market, for builders, FHA-insured borrowers can be a large portion of potential buyers (Figure 46. Type of Financing of New Single-Family Homes Built for Sale in the United States, 2020Figure 46). In the South, 25 percent of all homebuyers of newly built homes are FHA-insured homebuyers. In such a market, all other things being equal, builders would be more inclined to build to the code required by this Notice. In the Northeast, where only 1 percent of buyers of newly built homes are FHA-purchasers, builders may be less likely to comply.

[107] The average change in quality is a function of the construction rate, improvement in quality of every unit built, and loss rate of existing structures (DiPasquale and Wheaton, 1996).
[108] Blackley (1999) reviews the empirical literature concerning the sensitivity of construction to price changes and concludes that "residential construction varies directly with its price and is highly elastic." Long-run price elasticities for new construction (and not housing supply) range from 1 to as high as 13. How long is the long run? The research of Harter-Dreiman (2003) implies that 70 percent of the housing market adjustment to any shock occurs within 5 years and 90 percent occurs within 10 years. The effect of construction costs on construction activity is not as well researched. Indeed, many studies do not find a significant link between the costs of the structure and new construction. Sommerville (1999) suspects that the failure to detect causation stems from cost data not being adjusted for hedonic characteristics of homes (the type of housing being built). His study finds that the elasticity of construction starts with respect to the cost of structures is negative when the unit of production is adjusted for quality. The estimated price elasticity of starts per unit of "quality" is 14.76 and the cost elasticity is -13.87.
[109] The developer's profit equals the sales price of the home net of the cost of the structure and the price of the land. The profit, to be economically viable, must exceed the rate of return of an alternative investment. NAHB estimates the profit to be approximately 10 percent of the sales price.
[110] Assume that the discount rate of the developer is 3 percent or 7 percent, as set by OIRA. If the breakeven price for a developer were $200,000, then the annual cost of not selling the home would range from $6,000 to $14,000.

Figure 46. Type of Financing of New Single-Family Homes Built for Sale in the United States, 2020

	Homes (in Thousands)				Share of Homes (Percent)			
	Conventional	**FHA**	**VA**	**Cash**	**Conventional**	**FHA**	**VA**	**Cash**
Northeast	25	(Z)	1	2	89.3	**1.0**	3.6	7.1
Midwest	60	6	2	4	83.3	**8.3**	2.8	5.6
South	244	96	31	21	62.2	**24.5**	7.9	5.4
West	128	19	18	8	74.0	**11.0**	10.4	4.6
U.S.	**457**	**122**	**52**	**35**	**68.6**	**18.3**	**7.8**	**5.3**

Source: Annual Characteristics of New Housing, U.S. Census
Note: (Z) = suppressed.

A second incentive for adopting the IECC 2021 would be the receipt of a higher sales price due to a more energy-efficient design. Energy efficiency could also attract other prospective buyers, depending on the market demand for energy-efficient housing. The price premium from energy efficiency would not necessarily offset the cost of building to IECC 2021 but would serve to diminish any losses to the builder.

The costs to a developer of adopting the standard include the structural costs, loss of potential customers unwilling to pay the additional price, and any other distortions introduced by the regulation. The builder will build an affordable home to the IECC 2021 standard if:

- FHA-insured borrowers are an important part of the market for newly built homes;
- There is a sufficient market return from energy efficiency; and/or
- The builder is able to pass on some of the cost to the buyer.

Under these conditions, availability will not be adversely affected, but the type of home could change. Increasing the cost per square foot could lead the builder to construct slightly smaller homes.[111] Increasing costs could also lead the developer to postpone development until market circumstances are more favorable.

A second possibility is that the builder continues to build affordable homes but not to the IECC 2021 standard. This would be the case when and where:

- There are significant profits from building new homes for low-income homebuyers, even if not FHA-insured;
- FHA-insured borrowers are not a major part of the market, perhaps because conventional loans are relatively more affordable;
- Lower-income homebuyers do not place a significant premium on energy efficiency; or
- The builder is unable to pass on costs to the buyer.

The total supply of affordable housing would not be adversely affected, but new construction for FHA borrowers would decline. FHA-insured borrowers could adapt to the supply constraints by seeking a conventional loan or by purchasing an existing home with similar qualities.

[111] Developers build the types of homes that will sell quickly and at a higher difference between price and cost. The marginal revenue from a particular attribute is likely to be decreasing, while the cost is constant or decreasing, setting an optimal level of some attribute. If marginal costs increase, then the attribute would fall, and so would the value of the home. However, if the cost of energy efficiency is fixed, then we would not expect a change in characteristics, only in the decision to build.

The profit margin from building affordable housing could be so slim that any change in costs would lead to a very different development decision. One alternative would be to build housing for higher-income buyers. The IECC 2021 standard could be pursued if higher-income borrowers value energy efficiency, and if builders expect that there may be some higher-income households who would pursue an FHA loan. This new strategy would put the home out of reach of most FHA-insured borrowers and so would reduce the availability of affordable housing, albeit not housing for higher-income borrowers. Another strategy would be to postpone development and wait for conditions to change. This would lead to a temporary reduction of availability. If allowed by the local zoning ordinance, a builder may consider developing land for a use other than single-family residential.

The impact of the regulatory action will be gradual. If the supply or demand for the IECC 2021 homes is price-inelastic, then this Notice will improve the average energy efficiency of the housing stock. On average, 1 percent of the housing stock is added through new construction, of which 10 to 20 percent is financed through FHA-insured loans. If there is no change in these ratios (inelastic supply or demand), then the energy efficiency of 0.1 to 0.2 percent of the entire single-family housing stock will increase every year.[112]

At the other extreme of infinite price elasticity of demand or supply, builders would decide not to build to IECC 2021, or FHA-insured homebuyers would abandon new construction due to the costs of the IECC 2021. Higher-quality units would not be built, and there may even be a small decline in construction, which could diminish the overall housing stock in the long run. At the very worst, new construction would decline by a proportion equal to the fraction of FHA-insured borrowers purchasing newly built homes. Such a drastic outcome is unlikely. If FHA-insured homebuyers were to abandon a submarket, then they would be replaced by other buyers and construction would continue as normal. Additionally, the underlying demand of FHA-insured borrowers does not vanish: a unit not built to IECC 2021 can be resold as an existing unit to an FHA-insured borrower.

It is possible that some builders are already building to a higher standard than required by law. This is especially true for certain ASHRAE 90.1 standards that are estimated to have negative incremental construction costs. A survey of home builders jointly conducted by the Virginia Center for Housing Research and the National Association of Home Builders Research Center found that the majority of builders reported that they preferred to use materials that exceeded current code minimums (Koebel et al., 2004). However, other developers have expressed that building codes have become more aspirational rather than strictly safety-oriented and have pointed specifically to energy efficiency standards as an example of potential overreach. It can take longer than 3 years—the time between International Code Council updates of internationally adopted building code standards—to develop new building materials or products, during which building, and energy efficiency codes may have changed in ways that render the goods no longer usable. This may slow innovation in the building industry and overall development timelines (Kelly, 1996). Builders are not monolithic; they pursue different development strategies and approaches and will respond to higher building standards in different ways.

Housing Submarkets

The volume of transactions affected by this Notice relative to the entire housing market is an indicator of whether there could be market-wide impacts. Newly built homes are only a small portion of all sales.

[112] Accounting for losses of older housing, the average quality would increase by slightly more.

In 2020, the national average of the sale of newly built homes as a proportion of all units sold was 13 percent, ranging from 5 percent in the Northeast to 16 percent in the South.[113] FHA-insured loans finance approximately 18 percent of all new home sales. Thus, FHA-financed new construction loans represent only 2.3 percent of all market transactions (18 percent of 13 percent) at a national level.

There is significant regional variation. FHA-insured loans finance 1 percent of the purchases of newly built homes in the Northeast, 8 percent in the Midwest, 11 percent in the West, and 25 percent of purchases in the South. The purchase of newly built homes, financed by FHA-insured loans represents a very narrow submarket in the Northeast.

Figure 47. New Construction as a Proportion of All Home Purchases by FHA-Insured Borrowers

Region	2010	2015	2020	2021
Northeast	4.7	2.4	2.1	1.9
Midwest	6.9	3.8	4.6	4.8
South	17.3	15.3	23.2	24.8
West	11.1	8.8	13.5	15.2
Total	**11.7**	**9.6**	**15.0**	**16.0**

Source: Single-Family Data Warehouse

The regional differences in FHA-insured purchases of new construction stem from the price of newly built homes in comparison to existing homes and the pace of new construction. Construction is higher in quickly growing areas unfettered by building restrictions. As a portion of all home purchases (all homebuyers, new and existing homes), FHA-financed purchases of new construction range from slightly more than 0 percent in the Northeast to slightly less than 3.6 percent in the South.[114]

A subset of all home purchases would be a more accurate estimate of the transactions potentially affected by this regulatory action. Low-to-moderate- (LMI) and middle-income borrowers are a good proxy for the potential FHA borrower. Lower-income borrowers are more likely to shop in submarkets where the price is below FHA ceilings. HMDA data places the proportion of participants in these income groups at 56 percent of all borrowers (Table 2, CFPB, June 2020). Instead of potentially affecting only 2.3 percent of all market transactions (FHA-financed newly built homes/all home sales), the relative impact could be larger, at 4.1 percent of relevant transactions (FHA-financed newly built homes/all LMI and middle-income borrowers).[115]

The average homebuyer may buy a newly built home because new construction could be closely associated with the quality of home, size of the home, and location. Builders develop the kinds of homes

[113] These estimates are rough and are based on averages for 2019 and 2020 from two different data sets (National Association of Realtors Existing-Home Sales and the Survey of Construction).

[114] A finding of our previous analysis was that the portion of units that would have to be built to higher standards represented both a small fraction of HUD-USDA-assisted housing as well as the housing market overall. In the 16 states affected by the previous notice, we estimated that the units that would have to build to the higher 2009 IECC standard were 4.6 percent of all newly built single-family homes in those states and only 0.3 percent of all single-family sales in those 16 states. The low volume of new units affected in combination with the estimated low incremental cost per unit (approximately $1,000) drove the conclusion that any indirect effects on the supply or demand of single-family housing would be de minimis.

[115] 2.3 percent divided by 56 percent.

that are in demand. How closely any of these attributes are tied to new construction could make it harder for a homebuyer to find a close substitute. If there are many affordable and higher-quality homes already built, then the price elasticity of demand for new construction will be high. Homebuyers could avoid the cost of the IECC 2021 by buying homes built before its implementation.

Finding a close substitute may be more difficult in rural areas where the housing stock is thinner. The USDA guaranteed and direct loans are limited to eligible areas as defined by USDA, which exclude central cities. Thus, there could a greater relative burden on Section 502: about half of USDA's guaranteed and direct home loans are to borrowers in rural areas as defined by the 2010 Census, as compared to about one-fifth of FHA's (AHS, 2019).

The regulatory action is not expected to have an impact on the entire housing market but could affect individual submarkets. A housing "submarket" is part of the overall housing market and is distinguished by the type of housing available. [116] A submarket can be defined by the price of a home, the income of its occupants, the location, or structural features such as floor size, lot size, density, or age. [117] For some consumers, energy efficiency may be an important attribute. According to Zabel (2004), estimated price elasticities of demand for housing are much higher for models of demand that allow the price to vary by submarket than for models that treat the metropolitan area as one housing market. [118] An insight from all studies of housing submarkets is that the availability of close substitutes makes it easier for a household to escape costs. A cost increase in one submarket could lead to demand pressure in adjacent markets. The effect on availability across the entire housing market will depend upon the ease of substitution (cross-price elasticity of demand) between submarkets. HUD-USDA does not expect there to be noticeable spillover effects on availability in other submarkets given the relatively small size of FHA-insured purchases of new construction to other home purchases.[119]

Capitalization of Energy Efficiency Standard

The demand for a housing unit is intrinsically linked with its attributes, of which energy efficiency is one. A building that is energy-efficient should command a higher selling price. The value could stem from the reduction of operating costs (and thus as equivalent to income), as a hedonic variable affecting comfort, or even the satisfaction of being "green" (via "conspicuous conservation"). The individual buyer could be willing to pay a premium for the IECC 2021 home as high as the present value of energy savings. For

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[116] See Watkins (2001) for a review of the different methods of identifying submarkets.

[117] For example, Goodman and Thibodeau (1998) define 5 housing submarkets within a metropolitan area. The lowest cost one offers housing at 47 percent below the median price; some of the discount is due to structural characteristics, and the rest is due to lower school quality.

[118] What is the difference between substituting within a submarket and between submarkets? There is a slight but important difference. When approached as one market, every attribute is priced separately as if there were auctions for individual attributes. The result is a hedonic price that is the same for all housing units. The submarket approach separates the overall housing market by how easily homebuyers substitute between different types of units rather than characteristics. The difference is slight but allows for shoppers to search within a submarket and for producers to target production to a particular group. The concept of market segmentation is used to improve appraisal methods (Bourassa, et al., 2003) but it also useful in understanding the reaction to public policy.

[119] Just as consumers can substitute between different submarkets, so can builders to a limited extent. A general technique of measuring the elasticity of supply was suggested by McCloskey (1985) and summarized by Dacquisto and Rodda (2006). The elasticity of supply would depend on the proportion of quantity in the submarket to the broader market. HUD-USDA does not adopt this methodology because a major determinant of a housing submarket is location, which is fixed.

example, a buyer who values energy efficiency would pay $15,000 more for an IECC 2021 home than an IECC 2009 home (see Figure 7). The market price for energy-efficient design would be determined by bidding between different buyers, the home going to the highest bidder. The sales price will be somewhere between the value of the energy savings and the additional construction costs, the precise value determined by the bidding of other buyers. The buyer's consumer surplus is the difference between the value of the energy-efficient design to the consumer and the price paid. [120]

Whether the NPV of an energy-efficient investment is positive or negative will affect the market price of a structure and the incentives for building it. Receiving an incremental price increase of more than the incremental construction cost would be an incentive to develop to the updated code; receiving less than the incremental cost would be a disincentive (approximately $5,000, see Figure 7). If the seller experiences losses, then the builder may be able to pass on some of those losses to the buyer in the form of a higher price, especially for tight housing markets with high demand.[121]

In a market of goods with multiple characteristics, a builder should be able to match with a consumer who values the features of a home, such as energy efficiency, and make a mutually beneficial trade.[122] Estimating the implicit demand for an attribute of a multifaceted good such as housing and the willingness to pay is known as hedonic analysis. [123] Empirical studies suggest there is a statistically significant and positive influence of energy efficiency on real estate values (Laquatra, 2002). One study (Kahn and Kok, 2014) examines the residential market in California, and finds that a green label adds about 2.1 percent to the value of a home. This premium is slightly above the costs of bringing a home in compliance with the green labels (Energy Star, LEED, and EnergyPoint). Consistent with our discussion of submarkets, the researchers find spatial variation in the capitalization of energy efficiency.

Another study (Bruegge, et al., 2016) examines the premium placed on the Energy Star certification on homes in Gainesville, Florida. They find that there is a premium for these homes but that the premium diminishes when the home is resold. This finding could suggest that energy efficiency is a motivator for buying newly built homes. A different result from the research of Bruegge et al. (2019) is that the prices of homes in low-income submarkets with stricter building codes are reduced. This does not necessarily contradict the results of other studies. Bruegge et al. (2019) find higher prices for higher-income households.[124] Another two studies (Kahn and Kok, 2014; Bruegge et al., 2016) examine the effects of a label, which would be a voluntary option for the builder, rather than a code, which is obligatory. Aydin et al. (2020) find that energy performance certificates do not play a role in determining market value but that energy efficiency itself is capitalized into housing sales prices (about 2 percent for every 10 percent reduction of energy consumption).

A survey by the NAHB found that the median borrower was willing to pay an extra $5,000 upfront to save $1000/year in utility bills (Ford, 2019). This tradeoff would be equivalent to the resident receiving

[120] Capitalization of a benefit does not negate the benefit as long as sellers cannot price discriminate.
[121] If the PV of energy savings is greater than the incremental costs, then there will be greater profits for developers, consumer surplus, or both. If the PV of energy savings is less than the incremental costs, then there will be reduced profits for developers, lower consumer surplus, or both.
[122] In practice, builders rarely have the opportunity to design and customize a new home with a precise buyer in mind.
[123] The market price for an individual characteristic is referred to as the hedonic price and is represented by a "schedule" joining the prices of every structure.
[124] Such a differential price response could be attributed to varying demands for space versus energy efficiency.

10 years of benefits at a 20 percent discount rate or 30 years of benefits at 25 percent discount rate. A recent survey of the National Association of Realtors (2021) found that sixty five percent of realtors believed that energy efficiency was valuable in promoting residential units. However, the majority of realtors (57 percent) were "not sure" as to the impact of energy efficiency on sales price.

According to Eicholz et al. (2010), a commercial building with an Energy Star certification will rent for about 3 percent more per square foot and sell for as much as 16 percent more. The authors are able to disentangle the value of the label itself from the value of energy savings stemming from increased energy efficiency. Energy savings are important: a 10 percent decrease in energy consumption leads to an increase in value of about 1 percent over and above the rent and value premium for a labeled building.[125]

All of this empirical research shows that there are profit incentives to providing energy efficiency. Such a price gain would diminish any adverse effects on the supply of housing, although it is also evidence that bidding for energy efficiency could reduce affordability.

Homeownership and Availability

Ownership can provide many advantages: entry to submarkets that are not otherwise served by rental units; fixed-rate loans that offer greater certainty concerning housing payments; greater flexibility in use of the property; and pursuit of an avenue to build equity and wealth in the long run. Ownership can also lower the cost of housing.[126]

The high LTV of FHA-insured loans allows the purchaser to postpone almost all of the upfront incremental cost of building an energy-efficient home. For example, with a minimum down payment of 3.5 percent of the sales price and an upfront mortgage insurance premium of 1.75 percent of the loan, the borrower will pay about 5.2 percent of the incremental cost at purchase (0.035 + (1-0.035) x 0.0175 = 0.052), or only $250 for a $5,000 incremental cost. For a 5 percent increase in incremental cost, this additional upfront cost is equivalent to an increase of only 0.25 percent of the cost to the buyer at the date of purchase. Interest payments will also increase. Depending upon the interest rate and life of the loan, the future value (not discounted) of interest on the loan could increase the cost of the loan by 1.5 to 2 times the incremental cost.[127] But pressure on a household's budget from higher mortgage payments will be reduced or neutralized by savings in energy bills.

An FHA-insured borrower could be very price-sensitive and react to a price increase by reconsidering the decision to purchase. Most FHA-insured homebuyers (approximately 80 percent[128]) are first-time homebuyers, and so delay could be expected in submarkets where it is difficult to find close substitutes to new construction. Another possible reaction is to seek a different type of loan, one that is not FHA-

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[125] This result concerning the fundamental value of energy savings is important for energy efficiency guidelines that may not be as well recognized as Energy Star.

[126] The user cost of housing is given by the mortgage payment, maintenance, operating costs, taxes, and insurance less appreciation. New construction occurs in areas experiencing high price growth, which reduces the user cost of housing.

[127] The future value of interest cost is equal to the number of years multiplied by the annual mortgage payment less the loan balance during the life of the loan. For example, if the interest rate is 3 percent, the interest paid over thirty years would be 50 percent of the loan.

[128] First-time homebuyers generally make up about half of the market and are more heavily concentrated within FHA-insured loans, at about 80 percent of loans made.

insured, in order to buy a newly built home. The financing decision will depend on whether there are viable alternatives to FHA-insured loans. The average loan-to-value ratio for nonconventional loans is much higher than for conventional loans, allowing households with less savings to become homeowners. FHA's market share has varied greatly over time; in the last five years, the share of FHA-insured purchase loans has varied between 15 percent and 20 percent of all purchase loans. According to HMDA data for 2019,[129] about 40 percent of low-to-moderate income borrowers use non-conventional loans to finance home purchase; this is true for 40 percent of middle-income borrowers and 25 percent of high-income borrowers.[130] Most nonconventional loans (approximately 60 percent) are FHA-insured or guaranteed by the U.S. Department of Veterans Affairs (approximately 30 percent), or guaranteed or offered by the Farm Service Agency or the Rural Housing Service (approximately 10 percent for the last two).

Research reveals a modest change in demand for FHA-insured loans to the cost of FHA-insured loans among low-income borrowers and no response among higher-income borrowers (Bhutta and Ringo, 2016). This empirical work suggests that switching to a different submarket would be concentrated among the LMI borrowers. However, LMI borrowers will only be directly affected if they are in the market for more expensive newly built units.

FHA's program parameters could have an impact on a few buyers. The mortgage limit for most FHA-insured purchase loans is approximately $350,000 in "low-cost" areas; the ceiling is approximately $820,000 in "high-cost" areas. If passed on to the borrower, the cost of the energy efficiency requirement could push the sales price of new construction in some areas above the FHA limit and out of reach of the borrower. These will be rare cases: the average loan amount for FHA-insured mortgages in 2021 was $240,000 (FHA, 2021).[131] If such a restriction arises, then sellers may be willing to absorb the cost difference in slack markets, and buyers may be willing to pay the costs in tight markets.

Rental Housing and Availability

HUD-USDA does not expect that there will be any adverse impact on the availability of assisted rental housing from ASHRAE 90.1-2019. The estimate of the direct cost of construction of moving to this code is zero. If there are no changes in the cost of construction, then the change in quantity would be zero. Even if there were a slight increase in construction costs, the estimates of energy savings are sizeable enough such that we would expect the benefits to offset the costs. There could be some builders of multifamily properties who are doubtful and so may view the ASHRAE 90.1-2019 requirement as a net loss. This could impact the availability of affordable multifamily housing because most newly constructed affordable multifamily housing relies on one or more subsidy programs. For the hesitant developer, however, there remain incentives: FHA multifamily loans allow a higher LTV than other loans.

A report that HUD prepared for Congress in 2006 found that HUD spends about 10 percent of its budget on utility allowances to renters, through operating grants to PHAs or Section 8 contracts in privately

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[129] See Table 1 (p. 13), Data Point: 2019 Mortgage Market Activity and Trends. Consumer Financial Protection Bureau. https://files.consumerfinance.gov/f/documents/cfpb_2019-mortgage-market-activity-trends_report.pdf.

[130] Low- or moderate-income borrowers have family incomes less than 80 percent of the area median family income (AMFI); middle-income borrowers have family incomes that is at least 80 percent and less than 120 percent of AMFI; and high-income borrowers have income that is at least 120 percent of AMFI. Low-or moderate-borrowers constitute 30 percent of all borrowers, middle income 25 percent, and high-income 45 percent.

[131] https://www.hud.gov/sites/dfiles/Housing/documents/2021FHAAnnualReportMMIFund.pdf

owned multifamily buildings (HUD, 2006). Future cost savings generated by increased energy efficiency could be used to support additional rental assistance or other capital investments.

Market Failures and Availability

Much of the discussion concerning availability does not account for the possibility that the regulatory action could ameliorate market failures. According to the HUD-USDA 2015 analysis, "improved standards are expected to reduce operating costs per square foot, which will motivate consumers to increase demand for more housing at each rent level, and for developers or builders to respond to such demand with increased supply." The implicit conclusion of the 2015 analysis was that the regulatory action would eliminate barriers to efficiency and thus enhance the supply of energy-efficient housing and housing overall. If the regulatory action materially transforms both the ex-ante benefits of building and buying energy-efficient housing, then availability will not be harmed. Any adverse impacts on availability are diminished when there is a perceptible demand for energy-efficient homes. If some FHA-insured borrowers value improved energy efficiency, then they will be less willing to abandon their new construction for a close substitute.[132]

There is a caveat to this favorable prediction for availability: establishing minimum energy efficiency will not necessarily alter whether there is an economic reward for building energy-efficient housing. If energy-efficient housing was undersupplied before the Notice because energy efficiency was not valued, then producers would not necessarily react to the Notice by producing more energy-efficient housing. The outcome will depend upon the source of the market failure, and whether it rests with supply or demand.

Evidence of Impact on Availability

The extent and type of impact could vary by submarket and is largely an empirical question. Examining FHA new construction loans by the level of a state's energy efficiency standards can provide a rough indicator of the potential impact on availability. Having required a minimum standard equal to the 2009 IECC (in 2015), the FHA-insured purchase of new construction could depend on the strictness of the statewide code in relation to IECC 2009. If the IECC 2009 were a significant burden, then, other things being equal, FHA-insured new construction would be less common in areas where the state code is laxer and the compliance costs lower. For states with statewide requirements equivalent to the IECC 2009, then new construction for FHA borrowers would not be affected. The same is true for states where the standard is higher. We would expect a higher proportion of newly constructed homes purchased by FHA-insured borrowers in states where FHA's requirements are not binding.

At a national level, the percent of all FHA purchase loans for the purchase of new construction varies slightly depending on the energy code. In states where the statewide standard is less than what is required by HUD-USDA, the proportion of FHA loans for new construction appears similar to states that are stricter. For the states where the code is the same as IECC 2009 or above, the proportion of FHA-insured new construction loans is 16.9 percent (the weighted average of the states at least as restrictive as IECC 2009), which is slightly higher than the 15.1 percent share of states where energy codes are below IECC 2009.

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[132] A possible but unlikely outcome is that homebuyers who value energy efficiency would compete for newly built homes and outbid FHA-insured borrowers.

A clear pattern is not identifiable in either the Northeast or Midwest. In the South, the proportion of new construction is much higher in states above the IECC 2009 (32.7 percent) than in states below (16.6 percent). The South is where the greatest proportion of new construction occurs. In the West, the proportion of new construction is lower in states above the IECC 2009 (12.3 percent) than in states below (19.1 percent). Diverse climate zones, housing markets, and regulations around development could explain why different regions appear to respond differently to the energy standard. Despite the volatility of new construction, there is no compelling evidence that the availability of newly built owner-occupied housing will be adversely affected.

Figure 48. FHA-Insured Single-Family Forward Loans, 2021 Grouped by Region and Strictness of Statewide Energy Standard

United States			
State Energy Standard	**FHA New Construction**	**All FHA Purchase Loans**	**Percent New (%)**
Less than IECC 2009	14,800	98,300	15.1
Same as IECC 2009	61,900	445,800	13.9
Higher than IECC 2009	47,600	226,700	21.0
South			
State Energy Standard	**FHA New Construction**	**All FHA Purchase Loans**	**Percent New**
Less than IECC 2009	5,400	32,600	16.6
Same as IECC 2009	49,390	225,000	21.9
Higher than IECC 2009	37,900	116,000	32.7
West			
State Energy Standard	**FHA New Construction**	**All FHA Purchase Loans**	**Percent New**
Less than IECC 2009	8,090	42,275	19.1
Same as IECC 2009	5,490	32,500	16.9
Higher than IECC 2009	9,050	73,900	12.3
Midwest			
State Energy Standard	**FHA New Construction**	**All FHA Purchase Loans**	**Percent New**
Less than IECC 2009	1,310	23,400	5.6
Same as IECC 2009	5,650	122,000	4.6
Higher than IECC 2009	165	3,270	5.1
Northeast			
State Energy Standard	**FHA New Construction**	**All FHA Purchase Loans**	**Percent New**
Less than IECC 2009	0	0	---
Same as IECC 2009	1,410	66,000	2.1
Higher than IECC 2009	500	33,660	1.5

Source: Single-Family Data Warehouse for types of FHA loans, Department of Energy for energy codes

A parallel analysis of USDA Section 502 guaranteed and direct loans comes to similar conclusions. On average, there are about 6,000 new direct loans and 120,000 new guaranteed loans insured for purchase every year, or 12,000 total direct loans and 130,000 total guaranteed loans (including refinance or repair). A higher share of direct loans finance new construction in states with energy efficiency standards stricter than the 2009 IECC (50.3 percent versus a weighted average of 34.1 percent). For Section 502 guaranteed loans, which make up a much larger portion of USDA's insured housing stock, these shares are much closer (12.1 percent of loans are for new construction in states with standards higher than the 2009 IECC, as compared to a weighted average of 10.3 percent with standards the same as or lower than the 2009 IECC). By region, the Midwest has a higher share of both direct and guaranteed loans for new construction in states with lower standards; this is also true for guaranteed loans in the West.

Figure 49. USDA-Insured Direct Loans, Annual Average FY12-FY21 Grouped by Region and Strictness of Statewide Energy Standard

United States			
State Energy Standard	**New Construction**	**All Purchase Loans**	**Percent New (%)**
Less than IECC 2009	381	1,181	32.2
Same as IECC 2009	1,165	3,347	34.8
Higher than IECC 2009	818	1,625	50.3
South			
State Energy Standard	**New Construction**	**All Purchase Loans**	**Percent New (%)**
Less than IECC 2009	184	536	34.2
Same as IECC 2009	747	1,653	45.2
Higher than IECC 2009	170	381	44.6
West			
State Energy Standard	**New Construction**	**All Purchase Loans**	**Percent New (%)**
Less than IECC 2009	154	324	47.5
Same as IECC 2009	218	404	54.0
Higher than IECC 2009	582	736	79.1
Midwest			
State Energy Standard	**New Construction**	**All Purchase Loans**	**Percent New (%)**
Less than IECC 2009	43	321	13.4
Same as IECC 2009	191	1,152	16.5
Higher than IECC 2009	2	43	4.0
Northeast			
State Energy Standard	**New Construction**	**All Purchase Loans**	**Percent New (%)**
Less than IECC 2009	0	0	NA
Same as IECC 2009	9	138	6.8
Higher than IECC 2009	65	465	13.9

*New construction includes homes classified as “Build”, “Single-close”, and “Purchase new.”
Source: USDA; https://www.energycodes.gov/status

Figure 50. USDA-Insured Guaranteed Loans, Annual Average FY12-FY21 Grouped by Region and Strictness of Statewide Energy Standard

United States			
State Energy Standard	**New Construction**	**All Purchase Loans**	**Percent New (%)**
Less than IECC 2009	2,389	25,434	9.4
Same as IECC 2009	7,627	71,918	10.6
Higher than IECC 2009	3,049	25,199	12.1
South			
State Energy Standard	**New Construction**	**All Purchase Loans**	**Percent New (%)**
Less than IECC 2009	1,256	12,647	9.9
Same as IECC 2009	6,196	38,897	15.9
Higher than IECC 2009	2,183	7,840	27.8
West			
State Energy Standard	**New Construction**	**All Purchase Loans**	**Percent New (%)**
Less than IECC 2009	701	4,543	15.4
Same as IECC 2009	743	4,818	15.4
Higher than IECC 2009	642	7,267	8.8
Midwest			
State Energy Standard	**New Construction**	**All Purchase Loans**	**Percent New (%)**
Less than IECC 2009	431	8,245	5.2
Same as IECC 2009	637	25,908	2.5
Higher than IECC 2009	16	1,016	1.6
Northeast			
State Energy Standard	**New Construction**	**All Purchase Loans**	**Percent New (%)**
Less than IECC 2009	0	0	NA
Same as IECC 2009	51	2,295	2.2
Higher than IECC 2009	208	9,075	2.3

Source: USDA; https://www.energycodes.gov/status

Besides the quantity produced, energy efficiency standards could also affect the type of homes that are built. Bruegge, et al. (2019) investigate the impacts of state-level energy efficiency requirements on the housing market in California by comparing the characteristics of homes built before and after the implementation of a statewide building energy code. The researchers find that "stricter codes create a nontrivial reduction in homes' square footage and the number of bedrooms at the lower end of the income distribution." They estimate a 5 percent reduction in square footage for the bottom two income quintiles, and a much lesser impact for homes occupied by higher-income households. This empirical finding is consistent with builders altering the design of a home in response to higher costs per square foot.[133]

[133] The construction costs estimated by PNNL and others for compliance with new IECC or ASHRAE 90.1 codes are likely overestimates, as they do not account for behavioral adaptation by builders, who could respond to higher costs by builder smaller units.

Availability: Conclusion

In HUD-USDA's 2015 analysis, no adverse impacts on the availability of housing were projected. In this analysis, HUD arrives at a similar conclusion, albeit with some caveats. The availability of housing will not be adversely affected. However, under certain conditions, there could be a decline in the availability of new construction for homebuyers. Critical to availability is the response of both builders and consumers, which may vary by metropolitan area and housing submarket. If the supply and demand for housing within the relevant submarket are very price-elastic, then the market for newly built single-family units for FHA-insured borrowers would contract. However, price elasticity will be high only when there are close substitutes, implying that availability of shelter would not be harmed.

Underlying the assumption concerning the ease of substitution for homebuyers is that, in most cases, the purchase of a recently built existing home is an almost costless means of escaping any undesired costs passed on by builders of new homes. Another important factor allowing the homebuyer to avoid any upfront costs of the Notice is financing the purchase with a high-LTV and FHA-insured loan.

Builders are not compelled to build to the IECC 2021 standard. This is only required if they want to sell a newly constructed home to an FHA-insured borrower. Regions where construction activity is high are also areas where a nontrivial percentage of buyers of new construction are FHA-insured. There is an incentive to retain this portion of the market by building to the IECC 2021. Preliminary evidence shows that the earlier regulatory action of requiring IECC 2009 did not affect the purchase of new construction.

Energy efficiency has been shown to impart an economic value to buildings. The willingness to pay for this benefit will vary among homebuyers. If there is a sufficient proportion who realize those gains, then there will be a demand for housing built to the 2021 IECC that could partially counteract any adverse impacts on availability.

HUD does not expect the regulatory action to adversely affect the availability of rental housing assisted by HUD because there would be net benefits to the owners and operators of rental properties.

Any incremental impacts (either positive or negative) cease when the statewide energy code reaches or exceeds HUD's required regulations. If, for example, a state implements the 2021 IECC five years after the HUD-USDA Notice takes effect, then there would only be five years of impact.

Compliance

The standards must be enforced to have an incremental impact beyond what builders what the real estate industry would do in the absence of energy standards. The extent to which enforcement by HUD and USDA and compliance by builders would impose additional costs will vary by the stringency of enforcement practices and ease of compliance.

Of all of the programs affected by the energy standards, the greatest number of newly built units are single family homes insured by FHA. According to the FHA Single Family Housing Policy Handbook, one of the required documents that mortgagees must submit to FHA to finance new construction is Form HUD-92541, the Builder's Certification of Plans, Specifications, and Site. The current form in use,[134] which has an expiration date of January 31, 2024, includes information that the mortgagee must verify

[134] https://web.archive.org/web/20221026173411/https://www.hud.gov/sites/dfiles/OCHCO/documents/92541.pdf.

about the site, such as flood hazards, distance of the property from highways or railroads, and proximity to toxic waste and hazardous materials. The current form includes a checkmark for whether the property complies with "IECC (International Energy Conservation Code)", with no specific version of the IECC specified. Therefore, a unit built to any version of the IECC—not just the 2009 IECC, which is what the last update to the energy standards required—would comply. To optimize implementation and compliance with the new standards, this Notice should be accompanied by an update to Form HUD-92541 to ensure that mortgagees are only servicing newly constructed units meeting the 2021 IECC.

There is no evidence concerning the compliance by builders with the existing HUD and USDA energy codes. However, for typical buildings, DOE-sponsored residential code field studies found that the building industry is generally successful in implementing energy efficiency codes (US DOE, September 2022).[135] Compliance varies across different code components: parts that were tested to meet or exceed code requirements include windows, R-value insulation, building envelope tightness, and overall energy use intensity. Features with worse compliance include lighting and U-factor insulation.[136] A study of low-rise multifamily buildings found that some were designed to quality for additional energy efficiency certification programs, thus meeting higher standards.[137]

To facilitate compliance, the International Code Council has published a number of resources on compliance and enforcement, including model inspection forms.[138] They recommend developing a checklist for inspectors that would focus on the code requirements that have the highest impact on energy efficiency. For single-family homes, these priority design features include envelope tightness, window U-factor, window solar heat gain coefficient (SHGC), wall insulation (assembly U-factor), foundation insulation, ceiling insulation (R-value), lighting (percent high efficacy), and duct tightness.

Learning the new codes could be additional burden to architects. However, architects of multifamily projects for HUD should be sufficiently knowledgeable of energy efficiency and building codes such that they would be able to (1) familiarize themselves with the latest code requirements with little effort; (2) incorporate these requirements in plans and specifications; and (3) certify that the project complies with the latest IECC or ASHRAE codes.

For single-family projects, builders would need to familiarize themselves with the higher code standards and ensure that these are incorporated into plans and specifications. If architects are involved, they should be able to familiarize themselves with the latest code without additional training; for projects without architects, builders might need additional training. Training for building inspectors could be an additional cost of the rule for both HUD and USDA. Additional training might be necessary for designers, builders, developers, and architects.

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[135] See https://web.archive.org/web/20221026173346/https://www.energycodes.gov/sites/default/files/2021-07/NECC19_D2S1_Williams.pdf.

[136] See p. iv-v, https://web.archive.org/web/20221026173345/https://www.energycodes.gov/sites/default/files/2022-09/Combined_Residential_Energy_Code_Field_Study_Report.pdf. Seven states were studied: Alabama, Georgia, Kentucky, Maryland, North Carolina, Pennsylvania, and Texas.

[137] See https://www.osti.gov/biblio/1656655/.

[138] See https://web.archive.org/web/20221026173439/https://www.iccsafe.org/advocacy/iecc-compliance/.

Equity Impacts

Lower-income households face disproportionately higher energy burdens; they spend a higher share of their gross household income on energy costs.[139] Two-thirds of low-income households earning up to 200 percent of the federal poverty level face high energy burdens, spending more than 6 percent of their income on energy bills (Drehobl, Ross, and Ayala, 2020). Black, Hispanic, Native American, and older adult households, as well as families residing in manufactured housing and low-income households with a person with a disability, experience disproportionately high energy burdens. Improving energy efficiency for low-income households will increase on-time payments and reduce administrative costs through lowered spending on debt collection and shutoffs (Evens, 2015). But the same is true for housing. We need to ask whether lower-income households could be adversely affected by trading off lower energy costs for higher housing costs.

Expenditures on housing include spending on the structure itself as well as expenditures that enhance the comfort and quality of the housing: owned dwellings expenses,[140] rented dwellings, other lodging, utilities, fuels, public services, personal services related to care and domestic duties, maintenance and repair, housekeeping supplies, furniture, and appliances. As a category, the average expenditure share on housing is approximately 35 percent of all expenditures but is higher for lower-income households. Such a pattern serves as evidence that housing is a necessary good. The expenditure data are consistent with empirical estimates of the income elasticity of demand for housing and residential energy (positive but below one).

Figure 51. Expenditure Shares by Income Quintile (2020)

	First Quintile	Second Quintile	Third Quintile	Fourth Quintile	Fifth Quintile	Average
Total Expenditures	100.0	100.0	100.0	100.0	100.0	100.0
Housing	42.9	39.5	35.9	33.2	31.9	34.9
Shelter	26.4	23.5	20.9	19.3	18.7	20.5
Residential Energy	5.3	4.4	3.8	3.1	2.4	3.3
Ratio of Shelter to Energy	5.0	5.3	5.5	6.3	7.9	6.2

Source: BLS. “Residential energy” calculated by HUD as sum of electricity, natural gas, and fuel oil.

HUD estimates the category of residential energy expenditures by adding expenditures on electricity, natural gas, and fuel oil. Shelter expenditures are a much more consequential part of housing expenditures. Shelter outweighs residential energy by about 5-to-1 for the lowest income and about 6-to-1 for the average household. The ratio of shelter to energy expands with income, suggesting that reducing the cost of residential energy could be more beneficial to lower-income households.

Low-income households face energy insecurity as defined by the EIA, but also face housing insecurity. The data reveal the extent to which a tradeoff between shelter and energy costs can reduce gross expenditures on housing. The ratio of shelter to energy indicates that, for the first income quintile, the reduction in residential energy must be 5 times greater than the increase in shelter costs. The hurdle is stricter for higher-income households, indicating that lower-income households could be more

[139] https://web.archive.org/save/https://www.energy.gov/eere/slsc/low-income-community-energy-solutions
[140] According to BLS: “Mortgage principal repayments are payments of loans and are shown in Other financial information.”

favorably disposed to the tradeoff between energy and housing. PNNL predicts a 10.9 percent decrease in energy costs for multifamily units and an 8 percent decrease for single-family units from the IECC 2018 to 2021 update (Table ES.4., Salcido et al., July 2021). The lowest quintile would gain if the increase in shelter costs were no greater than 2.2 percent for multifamily housing and 1.6 percent for single-family.[141] This rough estimate does not account for the income and substitution effects for a change in relative prices. Another implicit assumption behind this calculation is a household's original choice of expenditures shares can be improved upon, an assumption which requires there to be a market barrier restricting choice.

Empirical studies of energy demand and the demand for energy efficiency may provide more insight as to whether the mandated energy efficiency is beneficial for lower-income households.[142] Energy efficiency is likely to yield greater improvements in the quality of life for low-income households. Lower-income households use energy in a non-discretionary manner, i.e., only as essential (Newman and Day, 1975). As further evidence, the rebound factor for low-income households is greater than for the average household (Aydin et al, 2017). Bakaloglou and Charlier (2021) also find a large rebound effect for low-income households, who have been limiting energy consumption due to income restrictions. Because poorer households tend to have worse quality homes with less efficient heating and poor insulation, they cannot easily adjust their energy consumption (Van Raaij, Verhallen, 1983) in response to fluctuating energy prices. Higher-income households, on the other hand, are less *willing* to reduce their energy consumption; the greatest potential for energy savings therefore comes from middle-income consumers. An extensive review of retrofit evaluations found that the percentage reduction of energy consumption was greatest for policies treating low-income households (Giandomenico et al., 2020).

Despite the advantages of energy efficiency, lower-income households are less willing than higher-income ones to accept longer payback periods for energy-efficient investments (Cunningham and Joseph, 1978). Houdé and Myers (2021) find that, although all consumers appear to value energy efficiency, higher-income households weigh operating costs more relative to the purchase price.[143] The results of Sahari (2019) imply a lower energy price elasticity of demand for energy-efficient technology. Some research has found that energy efficiency programs have a lower net benefit for low-income households than expected (Billingsley, 2014). McCoy and Kotsch (2021) stress that although savings may be less for low-income households, these same households may gain more in terms of the many private and public co-benefits of energy efficiency.

[141] Derived from the identity that housing = shelter + energy. The breakeven shelter increase of 2.2 percent for multifamily is equal to the 10.9 percent reduction in energy costs divided by 5, the ratio of shelter to energy for the lowest income quintile.

[142] A comprehensive review of 50 metropolitan areas in the United States estimates a price elasticity of demand for electricity around -0.9 to -0.6, which indicates that electricity is a relatively inelastic good (Alberini, Gans, and Velez-Lopez, 2011). This is because a minimum level of energy is a necessity, and there are no immediate substitutes for a different source of energy. A meta-analysis of 103 articles of residential electricity demand finds that the impact of income changes on electricity demand is greater than the impact of price changes in the long term (Zhu, et al., 2018). This means that long-term electricity demand is more dependent on household income than on the price of electricity. In the short term, residential electricity demand is almost price-inelastic and income-inelastic.

[143] This would make higher-income households less likely to make the type of inattention mistake discussed in the justification section.

Other research has found that, while the income of a household does have an impact on energy consumption, other factors have a larger effect, including household size, age of occupants, and structural dwelling characteristics (including the age of the building, its number of rooms, its insulation, and whether the unit is attached or detached) (Longhi, 2015; Brounen, Kok, and Quigley, 2012; Salari and Javid, 2017). Controlling for other factors like income, higher educational attainment is associated with lower energy consumption, or more energy savings (Salari and Javid, 2017). This may be because individuals who are more educated may have more information about saving energy in their buildings.

Our conclusion concerning the equity impacts of a minimum energy standard are nuanced. Lower-income households will benefit more from the existence of energy-efficient housing but may not be able to afford it. Empirical work has shown that residential energy is a necessary good. Reducing its price through energy efficiency requires an additional cost and one that lower-income households may not have the disposable income to accommodate. If, however, the Notice encourages the supply of energy efficiency in the affordable housing stock, then low-income households will gain. Precise impacts are likely to vary by housing market and climate zone.

Discussion of Alternatives

HUD and USDA could require the adoption of alternative energy efficiency standards to the 2021 IECC and ASHRAE 90.1-2019. For instance, HUD-USDA could require the adoption of a less stringent standard, such as the 2018 IECC or ASHRAE 90.1-2016. However, first and foremost, the statute requires HUD and USDA to update the standards to the most recent ones available, on the condition that they do not create an adverse impact. This would preclude the designation of less stringent standards if the proposed standards are not found to cause significant impacts on the availability or affordability of housing.

The 2009 IECC represented the first time the model energy code was designed to produce a more significant gain in energy efficiency—an estimated 15 percent energy savings, as opposed to the 1 to 2 percent savings of energy code updates since 1986.[144] The 2012 IECC was designed to create an even higher 18 percent energy savings. Between 2012 and 2018, however, significant gains in energy savings were stalled. The 2021 IECC was designed to create over 10 percent energy gains from the 2018 IECC.

Requiring an earlier version of the IECC and ASHRAE 90.1 would increase compliance costs for future updates to HUD-USDA energy efficiency standards, due to the administrative burdens imposed on housing producers to undergo multiple sets of updates as opposed to a single one to get to the most current codes.

A different alternative could be to require HUD and USDA housing to meet ASHRAE 90.2 as opposed to ASHRAE 90.1. ASHRAE 90.2 is a performance-based rather than prescriptive standard. Difficulties with ASHRAE 90.2 include its many additional pathways of compliance. A model code is complex and compliance is challenging enough that adding in many other options can complicate rather than simplify a producer's decision-making. In addition, ASHRAE 90.2-2018 (the most recent ASHRAE 90.2 standard) is more stringent than the IECC in terms of the efficiency level required.[145]

[144] See https://energyefficientcodes.org/iecc.
[145] See https://www.nrdc.org/experts/david-b-goldstein/setting-standard-climate-protective-homes.

An alternative to energy efficiency standards includes disclosure of information regarding energy efficiency. In Austin, Texas, home sellers are required to complete energy audits, though actual upgrades are not required.[146] However, given the market failures discussed previously, like behavioral inattention, where individuals have limited attention to process all information that is presented to them, additional information alone may not be able to solve issues of suboptimal energy efficiency.

A separate, more stringent alternative to the proposed rule could be a “stretch” standard. Some jurisdictions, like Boston, Massachusetts, have voluntarily adopted a stretch efficiency code, where new buildings must exceed base code standards by a certain percent (20 percent in the case of Boston[147]). Another more stringent alternative would be requiring compliance with certain energy efficiency standards when buildings are sold, rather than only when they are newly constructed or substantially renovated. This may be especially salient in built-out communities with little available land for new construction.[148] However, these alternatives may be overly costly for producers and would potentially create negative impacts on housing affordability or availability.

A separate alternative would be to implement a Pigouvian carbon tax on energy consumption set at the level of marginal damage, or a cap-and-trade program where a set number of permits are issued equivalent to the total amount of allowable emissions.[149] However, this would have to be administered by the IRS and would be outside the scope of either HUD’s or USDA’s authority.

Conclusion

Figure 52. Benefits and Costs from One Cohort of New Construction (Millions of Dollars)

	Annual or annualized at 3% discount rate	Annual or annualized at 7% discount rate	PV at 3% discount rate over 30 years	PV at 7% discount rate over 30 years
Benefit: Energy Savings	74.2	74.2	1,476	972
Benefit: Reduction in Greenhouse Gas Emissions	3.9	—	79	—
Construction Cost	27.4	41.6	560	560

In the first year of implementation, approximately 150,000 newly built units will be affected by IECC and 17,000 units by ASHRAE 90.1, for a total of about 170,000 units in a typical year. Our aggregate results indicate upfront costs of construction for one cohort of $553 million for the IECC update and $7 million for the ASHRAE update, for a total of $560 million per cohort. Construction loans allow builders to spread construction costs over time, and mortgage loans allow homebuyers to do the same. The aggregate annualized costs are $27.4 million at a discount rate of 3 percent and $41.6 million at a discount rate of 7 percent, with a time horizon of 30 years. The benefits for the projected energy savings

[146] See https://austinenergy.com/ae/energy-efficiency/ecad-ordinance/energy-conservation-audit-and-disclosure-ordinance
[147] See https://bcapcodes.org/beyond-code-portal/stretch-and-reach-codes/ for more stretch and reach code examples.
[148] See https://localhousingsolutions.org/housing-policy-library/energy-efficiency-standards for more information.
[149] Economists often argue that a Pigouvian tax or a system of tradable permits are the least-cost policies for reaching a social optimum when externalities from consumption exist. However, in a political environment where the optimal policies may be infeasible, energy standards are an imperfect alternative worthy of consideration.

are expected to be as high as $75.3 million annually for one cohort, including $74.2 million from the IECC update and $1.1 million from the ASHRAE update. The private gain is assumed to manifest itself in lower energy bills, increased comfort, or both.

The public benefits of reducing energy consumption are the avoided damage from reduced greenhouse gas emissions. Aggregate annual estimates for one cohort range from $1.6 million to $5.0 million annually for mid-range estimates and as high as $15.3 million annually for the upper-range estimate. The present value of reduced damages over 30 years at a discount rate of 3 percent[150] for one cohort would be $79 million for our mid-range estimates.

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[150] Guidance on the use of discount rates advises that 3 percent be used as a discount rate of time preference, sometimes referred to as the consumption discount rate, while the higher 7 percent is a rough measure of the return to capital.

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Appendix A: Data

Figure A1. Number of Newly Constructed Housing Units *Potentially* Affected by 2021 IECC Standard Annual Average 2019-2021

State or Territory	FHA Single Family	USDA Guaranteed Loan Program	USDA Direct Loan Program	FHA Single Family - Condos	PIH	HOME	Housing Trust Fund	Multi-family	Total
AK	42	27	19	3	0	35	19	0	145
AL	1,975	611	27	0	52	60	0	321	3,046
AR	1,024	453	52	0	0	145	12	164	1,850
AZ	4,595	391	90	54	0	97	0	432	5,659
CA	5,629	136	339	803	12	880	0	166	7,965
CO	2,701	151	42	65	13	199	1	682	3,854
CT	70	9	0	7	23	42	0	125	276
DC	17	0	0	8	12	0	0	137	174
DE	584	179	25	20	0	5	0	0	813
FL	19,178	1,119	189	24	146	366	87	1,477	22,586
GA	7,977	731	45	17	32	139	0	795	9,736
HI	77	61	39	40	3	33	0	0	253
IA	224	44	5	0	0	16	5	0	294
ID	812	134	13	0	0	56	29	11	1,055
IL	750	10	2	4	35	96	0	404	1,301
IN	1,890	205	137	1	0	121	0	49	2,403
KS	161	29	1	0	0	39	30	55	315
KY	798	277	66	13	0	71	0	188	1,413
LA	2,181	1,036	42	0	12	189	2	124	3,586
MA	174	7	7	11	0	20	0	491	710
MD	2,073	171	5	150	0	143	0	849	3,391
ME	116	48	16	0	0	40	30	15	265
MI	227	73	32	234	16	93	0	102	777
MN	542	99	16	1	3	120	0	607	1,388
MO	896	306	6	2	0	236	2	444	1,892
MS	1,048	304	43	2	1	0	0	0	1,398
MT	120	50	22	0	0	35	3	68	298
NC	4,977	1,211	165	2	7	724	25	1,321	8,432
ND	112	14	1	0	0	27	13	0	167
NE	177	9	1	0	0	17	0	297	501
NH	69	5	1	2	0	50	6	106	239
NJ	477	8	3	43	42	151	0	50	774
NM	751	21	26	0	0	11	15	115	939
NV	1,642	52	6	101	4	408	3	92	2,308

State or Territory	FHA Single Family	USDA Guaranteed Loan Program	USDA Direct Loan Program	FHA Single Family - Condos	PIH	HOME	Housing Trust Fund	Multi-family	Total
NY	233	5	6	3	15	262	0	1,445	1,969
OH	1,339	51	17	25	10	229	0	105	1,776
OK	1,464	288	41	0	0	34	13	81	1,921
OR	703	127	31	22	0	142	12	38	1,075
PA	697	78	13	4	43	90	0	85	1,010
RI	64	0	3	1	0	226	23	35	352
SC	4,169	992	87	3	0	3	0	236	5,490
SD	148	49	16	1	0	44	75	12	345
TN	3,355	644	55	9	2	124	30	751	4,970
TX	32,070	1,670	98	325	83	39	57	6,684	41,026
UT	1,679	417	127	103	0	243	0	476	3,045
VA	2,119	416	71	178	12	7	45	924	3,772
VT	10	4	2	0	0	85	24	9	134
WA	1,529	128	81	45	15	4	6	413	2,221
WI	168	24	7	0	5	59	0	173	436
WV	298	221	3	0	0	107	10	71	710
WY	55	32	3	0	0	85	1	18	194
Total	**114,184**	**13,129**	**2,143**	**2,325**	**598**	**6,475**	**578**	**21,243**	**160,675**
Total excluding states with 2021 IECC	*107,018*	*12,859*	*1,722*	*1,478*	*571*	*5,478*	*548*	*20,655*	*150,329*

Notes
Totals may not equal the sum of the parts due to rounding errors.
60.8% of MF units are in buildings with 1 to 3 floors (source: REAC Inspected Buildings, 2017-2021)
PIH includes Choice Neighborhoods, HOPE VI, Low Income Rental, Low Income/Fair Market Rent, and Mixed Finance.
HOME excludes manufactured housing.
MF includes FHA NC/SR Apts. and HFA Risk Sharing.

Figure A2. Number of Newly Constructed Housing Units *Potentially* Affected by ASHRAE 90.1-2019 Annual Average 2019-2021

State	PIH	HOME	Housing Trust Fund	Multifamily	Total
AL	34	29	0	207	270
AK	0	18	13	0	31
AZ	0	58	0	278	336
AR	0	67	8	105	180
CA	8	378	0	107	493
CO	8	72	0	440	520
CT	15	22	0	81	118
DE	0	2	0	0	2
DC	7	0	0	89	96

State	PIH	HOME	Housing Trust Fund	Multifamily	Total
FL	94	124	56	953	1,227
GA	21	80	0	513	614
HI	2	0	0	0	2
ID	0	25	17	7	49
IL	22	56	0	260	338
IN	0	60	0	32	92
IA	0	3	3	0	6
KS	0	4	19	36	59
KY	0	34	0	122	156
LA	8	105	1	80	194
ME	0	21	19	10	50
MD	0	77	0	547	624
MA	0	9	0	316	325
MI	11	54	0	65	130
MN	2	73	0	391	466
MS	0	0	0	0	0
MO	0	138	1	286	425
MT	0	19	2	44	65
NE	0	0	0	191	191
NV	3	216	2	59	280
NH	0	33	4	69	106
NJ	27	75	0	32	134
NM	0	5	9	74	88
NY	10	156	0	932	1,098
NC	4	79	0	852	935
ND	0	17	8	0	25
OH	7	83	0	68	158
OK	0	0	7	52	59
OR	0	92	8	24	124
PA	27	45	0	54	126
PR	41	86	0	0	127
RI	0	2	15	23	40
SC	0	10	0	152	162
SD	0	63	47	8	118
TN	1	9	16	484	510
TX	54	114	36	4,310	4,514
UT	0	1	0	307	308
VT	0	38	16	5	59
VA	8	38	9	596	651
VI	0	0	0	0	0

State	PIH	HOME	Housing Trust Fund	Multifamily	Total
WA	10	47	4	266	327
WV	0	5	6	46	57
WI	4	41	0	111	156
WY	0	10	1	12	23
Total	**387**	**2,707**	**327**	**13,696**	**17,117**
Share to Total (%)	***2.3***	***15.8***	***1.9***	***80.0***	***100***
Total excluding states with 2019 ASHRAE-90.1	*403*	*2,229*	*299*	*12,889*	*15,820*

Notes

60.8% of MF units are in buildings with 1 to 3 floors (Source: REAC Inspected Buildings, 2017-2021)

PIH includes Choice Neighborhoods, HOPE VI, Low Income Rental, Low Income/Fair Market Rent, and Mixed Finance.

HOME excludes manufactured housing.

MF includes FHA NC/SR Apts. and HFA Risk Sharing.

Figure A3. Status of State IECC Adoption

State	Current Code	Effective Equivalent
Alabama	2015 IECC with amendments	2009 IECC
Alaska	None statewide	No statewide code
Arizona*	Home rule	<2009 IECC
Arkansas	2009 IECC with amendments	<2009 IECC
California	2019 Building Energy Efficiency Standards	2021 IECC
Colorado	Home rule	No statewide code
Connecticut	2015 IECC with amendments	2009 IECC
Delaware	2018 IECC	2018 IECC
District of Columbia	2015 IECC with amendments	2018 IECC
Florida	2018 IECC with amendments	2009 IECC
Georgia	2015 IECC with amendments	2009 IECC
Hawaii*	Home rule	2015 IECC
Idaho	2018 IECC with amendments	2009 IECC
Illinois	2018 IECC with amendments	2009 IECC
Indiana	2018 IECC with amendments	2009 IECC
Iowa	2012 IECC with amendments	2009 IECC
Kansas	Home rule	No statewide code
Kentucky	2009 IECC	2009 IECC
Louisiana	2009 IECC	2009 IECC
Maine	2015 IECC with amendments	2015 IECC
Maryland	2018 IECC with amendments	2018 IECC
Massachusetts	2018 IECC with amendments	2018 IECC
Michigan	2015 IECC with amendments	2009 IECC
Minnesota	2012 IECC with amendments	2009 IECC
Mississippi	None statewide	No statewide code
Missouri	Home rule	No statewide code
Montana	2018 IECC with amendments	2009 IECC
Nebraska	2018 IECC	2018 IECC
Nevada	2018 IECC with amendments	2009 IECC
New Hampshire	2018 IECC with amendments	2009 IECC
New Jersey	2018 IECC with amendments	2009 IECC
New Mexico	2018 IECC with amendments	2009 IECC
New York	2018 IECC	2018 IECC
North Carolina	2015 IECC with amendments	2009 IECC
North Dakota	Home rule	No statewide code
Ohio	2018 IECC with amendments	2009 IECC
Oklahoma	2009 IECC with amendments	2009 IECC
Oregon	2018 IECC with amendments	2018 IECC
Pennsylvania	2018 IECC with amendments	2018 IECC
Rhode Island	2018 IECC with amendments	2009 IECC
South Carolina	2009 IECC	2009 IECC
South Dakota	Home rule	No statewide code
Tennessee	2018 IECC with amendments	<2009 IECC
Texas	2015 IECC	2018 IECC
Utah	2015 IECC with amendments	2009 IECC
Vermont	2018 IECC with amendments	2021 IECC
Virginia	2018 IECC with amendments	2009 IECC
Washington**	2018 Washington State Energy Code	2021 IECC
West Virginia	2009 IECC	2009 IECC
Wisconsin	2009 IECC with amendments	2009 IECC
Wyoming	Home rule	No statewide code

Source: U.S. Department of Energy (https://www.energycodes.gov/status/residential) as of March 31, 2022

*A review of the codes in place in jurisdictions across the state indicates that 86% (Hawaii) and 82% (Arizona) of the population is covered by codes at this level.

**The Washington State Energy Code is based on the 2018 IECC but with significant amendments.

Figure A4. Status of State ASHRAE 90.1 Adoption

State	Current Code	Effective Equivalent
Alabama	90.1-2013	90.1-2013
Alaska	No statewide code	No statewide code
Arizona*	Home rule	<90.1-2007
Arkansas	2009 IECC and 90.1-2007	90.1-2007
California	2019 Building Energy Efficiency Standards	90.1-2019
Colorado	Home Rule	No statewide code
Connecticut	2015 IECC and 90.1-2013	90.1-2010
Delaware	2018 IECC and 90.1-2016	90.1-2013
District of Columbia^	90.1-2013	90.1-2019
Florida^	2018 IECC and 90.1-2016	90.1-2013
Georgia^	2015 IECC and 90.1-2013	90.1-2013
Hawaii*	Home rule	90.1-2013
Idaho	2018 IECC and 90.1-2016	90.1-2013
Illinois	2018 IECC and 90.1-2016	90.1-2013
Indiana	90.1-2007	90.1-2007
Iowa	2012 IECC and 90.1-2010	90.1-2007
Kansas	Home rule	No statewide code
Kentucky	2012 IECC and 90.1-2010	90.1-2007
Louisiana	90.1-2007	90.1-2007
Maine	2015 IECC and 90.1-2013	90.1-2013
Maryland	2018 IECC and 90.1-2016	90.1-2013
Massachusetts^	2018 IECC and 90.1-2016	90.1-2019
Michigan^	2015 IECC and 90.1-2013	90.1-2013
Minnesota^	2018 IECC and 90.1-2016	90.1-2010
Mississippi	No statewide code	No statewide code
Missouri	Home rule	No statewide code
Montana	2018 IECC and 90.1-2016	90.1-2013
Nebraska	2018 IECC and 90.1-2016	90.1-2013
Nevada	2018 IECC and 90.1-2016	90.1-2013
New Hampshire	2015 IECC and 90.1-2013	90.1-2010
New Jersey	90.1-2016	90.1-2016
New Mexico^	2018 IECC and 90.1-2016	90.1-2013
New York^	2018 IECC and 90.1-2016	90.1-2016
North Carolina^	2015 IECC and 90.1-2013	90.1-2010
North Dakota	Home rule	No statewide code
Ohio	2012 IECC and 90.1-2010	90.1-2007
Oklahoma	2006 IECC and 90.1-2004	<90.1-2007
Oregon	90.1-2019	90.1-2019
Pennsylvania	2018 IECC and 90.1-2016	90.1-2013
Rhode Island^	2018 IECC and 90.1-2016	90.1-2013
South Carolina	2009 IECC and 90.1-2007	90.1-2007
South Dakota	Home rule	No statewide code
Tennessee	2012 IECC and 90.1-2010	90.1-2007
Texas	2015 IECC and 90.1-2013	90.1-2013
Utah	2018 IECC and 90.1-2016	90.1-2013
Vermont^	2018 IECC and 90.1-2016	90.1-2019
Virginia^	2018 IECC and 90.1-2016	90.1-2013
Washington**	2018 Washington State Energy Code	90.1-2019
West Virginia	90.1-2010	90.1-2010
Wisconsin^	2015 IECC and 90.1-2013	90.1-2010
Wyoming	Home rule	No statewide code

Source: U.S. Department of Energy (https://www.energycodes.gov/status/commercial) as of March 31, 2022

*A review of the codes in place in jurisdictions across the state indicates that 86% (Hawaii) and 82% (Arizona) of the population is covered by codes at this level.
**The Washington State Energy Code is based on the 2018 IECC but with significant amendments.
^ When an amendment impacting energy efficiency can be quantified using DOE Prototype Building Models, they were captured in the analysis.

Notes:
1. A home rule state is one where codes are adopted and enforced at the local level. Some home rule states will have a mandate that jurisdictions can go above code but also have to meet a certain minimum code. In general terms, the idea of home rule is defined as the ability of a local government to act and make policy in all areas that have not been designated to be of statewide interest through general law, state constitutional provisions, or initiatives and referenda.

2. States with extensively different baseline codes for which conducting custom analysis would be cost prohibitive and out of scope of this analysis.

3. For states adopting both IECC and 90.1, the IECC code is usually analyzed as the state current code in this study except for states with extensive amendments to the IECC.

Appendix B: How Incremental Effects Vary with Square Footage

HUD expects that the incremental effects of adopting energy standards will be smaller for HUD units than for the model units of the PNNL. The primary difference would stem from square footage, which has an impact on both energy consumption and the costs of construction. The average FHA-insured home has approximately 2,000 square feet, whereas the PNNL model home is close to 2,400 square feet (20 percent larger). An unanswered question is how the incremental changes in energy expenditures and incremental constructs will change for a smaller home. One approach is to use the PNNL estimate as an upper bound. A complement to that approach is to estimate how the benefits and costs will change for a different size dwelling unit.

Energy Expenditures

To approximate energy expenditures as a function of square footage, HUD uses the microdata from the 2015 Residential Energy Consumption Survey of the Energy Information Administration. We regress the natural logarithm of energy expenditures of a household, ln(E), on the square footage, ln ($SQFT$), of the structure. The natural logarithm transformation allows us to interpret the coefficient on square footage as an "elasticity" of energy expenditures with respect to square footage.

$$\ln(E_i) = \alpha + \beta \cdot \ln(SQFT_i) + \epsilon_i$$

The square footage coefficient, β, reveals the shape of the energy expenditure to square footage relationship. A coefficient greater than 0 indicates a positive relationship; greater than 0 and less than 1 indicates that a proportional increase in square footage leads to a less than proportional change in expenditures; equal to 1 indicates that a proportional change in square footage leads to an equivalent proportional change in energy expenditures; and greater than one that the change in energy expenditures accelerates. The error term captures energy expenditures not explained by square footage.

We estimate this equation separately for four different types of housing and include dummy variables for the IECC-defined climate zone. The 95 percent confidence interval of the square footage coefficient is greater than zero and less than one. Energy expenditures increase with square footage but by a diminishing amount.

Housing Type	**ln (SQFT) Coefficient**	**95% Confidence Interval**	**t-statistic**	**Observations**
Single Family Detached	0.34	0.32 to 0.37	24.9	3,752
Single Family Attached	0.31	0.24 to 0.39	8.1	479
Apartment Building with 2-4 Units	0.29	0.14 to 0.45	3.7	311
Apartment Building 5 or more	0.42	0.34 to 0.50	10.1	858

The elasticity is approximately 0.33. For every 10 percent change in square footage, energy expenditures will change by 3.3 percent.

We can use the estimate of energy expenditures by square footage to derive a rough approximation of how the incremental change in energy in expenditures from energy-saving technology would vary by square footage.

The linear function can be transformed to a multiplicate relationship by exponentiating both sides of the linear regression.

$$E_i = e^{\alpha} \cdot SQFT_i{}^{\beta}$$

In this formulation, β becomes an exponent on square footage and α yields a multiplier. If we model an improvement in technology as decreasing α, then the occupant in a home with improved technology will spend less on energy.[151] The reduction in energy expenditures, ΔE, from a change from IECC 2018 to 2021 would be

$$\Delta E_i = e^{\alpha\_IECC2021} \cdot SQFT_i^{\beta} - e^{\alpha\_IECC2018} \cdot SQFT_i^{\beta}$$

The energy savings would vary with the size of the home. The ratio of energy savings for two differently sized homes will follow the ratio of their square footages.

$$\frac{\Delta E_2}{\Delta E_1} = \left(\frac{SQFT_2}{SQFT_1}\right)^{\beta}$$

If home 2 is the standard PNNL home of approximately 2400 sq ft and home 2 is the approximately 2000 square foot home insured by FHA, then

$$\frac{\Delta E_2}{\Delta E_1} = \left(\frac{2{,}376}{2{,}000}\right)^{0.33} = 1.186^{0.33} = 1.058$$

Although the square footage of the larger home is almost 20 percent greater, energy expenditures are only about 6 percent greater. The annual energy savings by PNNL for their model single-family home of the roughly 2,400 square feet of the change from IECC 2021 to 2018 is $210. Using the ratio calculated the above, the equivalent energy savings for 2,000 square foot home would be $198 ($210/1.06).

Incremental Costs of Construction

The incremental costs of construction from a change in standard is likely to vary by the change in the building code and by the size and shape of the home. Some of the costs may be fixed and will not vary with the size of the home. Others will vary with wall area, type of roof, type of foundation, windows, perimeter of the building. In general, however, the compliance costs will increase with the size of the home. Table 10 of the June 2021 PNNL study provides a summary of the incremental costs of construction of IECC 2021 from IECC 2018. Variable costs include higher standards for wall insulation in climate zones 4 and 5, slab floor insulation for climate zones 3, 4, and 5, ceiling insultation for most climate zones, higher efficiency windows in climate zones 3 and 4. Fixed costs include heat recovery ventilation in climate zones 7 and 8, and efficiency options for water heaters.

[151] The energy efficiency could also be modeled as a change in the elasticity but doing this would make it impossible for us to estimate how energy savings vary with square footage.

Estimated Incremental Cost of Construction for IECC 2018 to IECC 2021 Single-Family Homes							
Climate zone	Total Cost PNNL Home ($)	Fixed Cost ($)	Variable Cost ($)	Variable Cost Per sq ft ($)	Total Incremental Cost Smaller FHA Home	Percentage Change in Total Costs (%)	Weighting (%)
1	936	830	106	0.04	919	-1.8	4.30
2	1,530	830	700	0.29	1,419	-7.2	22.43
3	1,859	830	1029	0.43	1,696	-8.8	29.04
4	3,687	830	2857	1.20	3,235	-12.3	19.49
5	3,569	830	2739	1.15	3,136	-12.1	19.51
6	1,477	830	647	0.27	1,375	-6.9	4.68
7	2,980	2330	650	0.27	2,877	-3.5	0.53
8	2,982	2330	652	0.27	2,879	-3.5	0.02
National*	**2,424**	**838**	**1,585**	**0.67**	**2,173**	**-10.4**	**100**
*Although HUD used PNNL's weighting factors to calculate the averages, there may be slight differences between the weighted averages presented in this table and PNNL's tables.							

When there are fixed costs, then the percentage in incremental costs will be less than any variable costs related to the size of the home. These are all HUD calculations derived from PNNL data presented in the National Cost Effectiveness Report. The estimates of the cost per square foot were derived from PNNL's total cost estimate, their description of how costs were estimated, and their description of the square footage of the home. HUD estimated the variable cost from the accounting identity TC = FC + VC, where fixed costs were taken from Table 10 of their report. The variable cost per square foot is then estimated as the variable cost divided by the square footage of the PNNL's model single family home of 2,376 square feet. The total incremental cost for a typical FHA home is then the fixed cost plus the per square foot cost times 2,000 square feet. A linear function is assumed.

A conclusion that emerges is that the proportional decline in incremental costs will not be as great as the proportional decline in square footage. When there are both fixed costs and variable costs, the relative change in costs is greater when fixed costs are a lower proportion of total costs. Square footage falls by approximately 15 percent. For all climate zones, the decline is costs is less, and greatest in climate zones 4 and 5. The weighted average of the decline in incremental costs for the 2018 to 2021 of smaller homes is approximately 10 percent.

Appendix C: Algebra of NPV

The present value of all energy-related costs is a negative flow over the lifetime of the project.

$$Costs = \sum_{t=1}^{T} \frac{E\ (IECC, t, \bar{x})}{(1+\rho)^{t-1}} + C(IECC, \bar{z})$$

A recommended design strategy, $IECC$, that lowers the NPV of costs, would create economic surplus through an advantageous trade-off between construction costs, C, and energy bills, E.

A more stringent energy code can be expected to lead to lower energy expenditures at every time period, t, from the first year of the investment until the end of the planning horizon, T. Periodic energy expenditures will vary by a vector of other variables, $\bar{x}$, such as the climate zone, structural characteristics of the unit, size of the unit, local utility prices and type of fuel, and the type of resident. Future energy bills are discounted, at rate ρ, to derive a present value.[152] The design standard is prescribed by the IECC and so the cost of construction will vary with the specific code. The cost of complying with a specific code will vary with a range of variables, represented by the vector $\bar{z}$.

The NPV of the change in energy standards is given by the change in energy expenditures as a result of the change in standards and the change in construction cost. In this formulation, a negative value of the change in NPV would show that the policy reduced total costs. Because it is a negative flow, a reduction of the NPV is equivalent to a positive flow for the resident.

$$\Delta NPV = \sum_{t=1}^{T} \frac{[E\ (IECC'', t, \bar{x}) - E\ (IECC', t, \bar{x})]}{(1+\rho)^{(t-1)}} + [C(IECC", \bar{z}) - C(IECC', \bar{z})]$$

The original $IECC$ is represented by $IECC'$ and the new one by $IECC''$. The impact of the requirement will depend upon existing state requirements. A breakeven condition for the design standard for an individual structure *i* would be given by the present value of energy savings exceeding the incremental cost of construction.

Equity Financing

To determine the incremental change is cost effective, HUD compares the present value of energy savings, over the lifetime of the investment with the initial cost.

$$NPV = PV \cdot \big(-\Delta E_i(1)\big) - \Delta C_i$$

The present value is the multiple of a present value multiplier PV

$$PV = \frac{(1+\rho)}{(\rho - g)} \cdot \left(1 - \left(\frac{1+g}{1+\rho}\right)^T\right)$$

for which *g* is the real annual growth rate of energy prices, *ρ* is the annual discount rate, and T is the lifetime of the investment. The stream of benefits is assumed to begin immediately upon investment.

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[152] The exponent for the discount factor is t-1 rather than t because we treat the first-year energy bills as occurring in the same year as construction.

The present value multiplier of energy savings increases with energy price growth and the lifetime of the investment and decreases with the discount rate.

Debt Financing

The NPV of the investment is favorable if the present value of energy savings outweighs the upfront increase in costs, given by the condition of the present value multiplier being greater than the simple pay back (incremental cost divided by first year energy savings) or

$$PV_B^E \cdot -\Delta E > \Delta C$$

or

$$PV_B^E > \frac{\Delta C}{-\Delta E} = t^*$$

Where PVBE is the PV multiplier to the buyer of future energy savings.

When the buyer borrows then it is different, the upfront cost is the down payment, and the periodic costs are the annualized costs of the loan. The NPV is positive is

$$PV_B^E \cdot -\Delta E > [(1 - LTV) \cdot \Delta C] + \left[PV_B^M \left(\frac{LTV \cdot \Delta C}{PV_L^M}\right)\right]$$

The first term in square brackets is the down payment and the second term is the present value to the borrower of mortgage payments where PVM is the present value of the stream of mortgage payments to the borrower and to the lender. This simplifies to the condition

$$PV_B^E > \left[(1 - LTV) + LTV \cdot \left(\frac{PV_B^M}{PV_L^M}\right)\right] \cdot \frac{\Delta C}{-\Delta E}$$

The costs to the buyer will be reduced by debt only if the term in square brackets is less than one. For this to be the case if

$$PV_B^M < PV_L^M$$

Or if the discount rate of the lender is less than the discount rate of the borrower. If the inequality is reversed then debt is more expensive, and if there is an equality, there is no difference between the NPV of the project versus debt-financing (abstracting from additional loan fees).

For example, suppose that the discount of the buyer/borrower is 7 percent, the lender 3 percent, and the LTV 95 percent then the "debt-deflator" is approximately 0.67 (0.05 + 0.95 x (13.3/20.2). If both lender and borrower face the same discount rate, for example 3 percent, then multiplier is 1 (0.05 + 0.95 x (20.2/20.2). If the interest rate is higher than the discount rate, then the cost of the project is inflated by interest costs. For example, if the lenders discount rate is 7 percent and the borrower's 3 percent the cost inflator would be 1.49 (0.05 + 0.95 x (20.2/13.3).

Appendix D: NAHB Estimates of Construction Cost

A cost-effectiveness analysis commissioned by the National Association of Home Builders (NAHB) and conducted by Home Innovation Research Labs estimates higher incremental costs ranging from $6,548 to $9,301 per house on average, though as high as $11,900 (Home Innovation Research Labs, June 2021).[153]

NAHB concluded that energy savings from adopting the code would range from 6.4 percent to 11.6 percent depending upon the additional option chosen. For the basic package plus the water heater option, NAHB found a reduction of 9.7 percent of energy expenditures. This range is similar to the estimate reported by PNNL of 8 percent for single-family homes (Table 11 of Energy Savings Analysis)[154].

Incremental Effects for Single Family Home IECC Update 2018-2021

Variable	PNNL	NAHB
Incremental Cost ($)	$2,372	$6,548
First Year Energy Savings ($)	$210	$207
Simple Payback (Years)	11.3	31.6
Sources: Construction cost, Table 7 for NAHB, Table 11 for PNNL. Incremental cost includes the Water Heater Option. Energy Savings are calculated from Table 9 for NAHB ($2,129 – $1,922) and for PNNL from Figure 12 of this report. Simple paybacks calculated by HIUD.		

There is a significant difference in the incremental cost estimate, which is almost three times higher than the estimate by PNNL for single-family homes. We would expect there to be slight differences in the cost estimates given the variety of building types, methods of compliance, costs of materials, and quantity of materials. HUD attributes such a large difference to two factors: NAHB's assumption of a high profit margin and difference between the shapes of the model homes used by PNNL and NAHB.

The representativeness of the NAHB and PNNL data are not equivalent. The set of prototypes PNNL uses in determinations are designed to represent the majority of the new residential building construction stock in the United States using a combination of U.S. Census, RECS, and NAHB data. DOE's established methodology uses a suite of representative residential prototype buildings, including a single-family and a low-rise multifamily residential building, each with four different foundation types (i.e., slab-on-grade, vented crawlspace, heated basement, unheated basement) and four heating system types (i.e., gas furnace, electric resistance, heat pump, fuel oil furnace). The Standard Reference House for NAHB is primarily based on the results of the 2008-2009 Annual Builder Practices Survey (ABPS). The ABPS is an annual national survey of builders that gauges national and regional building practices and material use. This survey represents a comprehensive source of general housing characteristics in the United States and contains information on building square footage, wall square footage, climate-based foundation type, climate-based wall construction type, and other residential construction characteristics. The parameters represent the average (mean) values from the survey for building areas and features not dictated by the 2006 IECC.

[153] https://www.nahb.org/-/media/NAHB/advocacy/docs/top-priorities/codes/code-adoption/2021-iecc-cost-effectiveness-analysis-hirl.pdf
[154] https://www.energycodes.gov/sites/default/files/2021-07/2021_IECC_Final_Determination_AnalysisTSD.pdf

NAHB calculates the unit cost of any change and adds to that an overhead and profit premium of approximately 27 percent. For example, the incremental cost to the builder of installing a square foot of ceiling insulation is 59 cents per square foot, which is derived by inflating the 46-cent incremental cost by the overhead premium. The total incremental cost to the producer is given by the inflated unit cost of 59 cents and the quantity (1,875 square feet of ceiling insulation) to settle on an estimate of $1,106. The cost paid by the consumer is assumed to be the cost to the producer plus a return of 23.5 percent on the change in costs. The cost to the consumer of requiring thicker ceiling insulation would then be $1,366 (1.235 x $1,106).[155] Adding these markups on incremental costs would inflate the cost estimate by 57 percent (1.27 x 1.235).

The design of the home plays a role by determining the quantity of insulation. The model single-family homes of PNNL are similar in terms of living space (floor area). The NAHB model is less dense, however, and has more of its floor area in the first floor than the second area. A low-density design leads to larger areas exposed to the exterior and in need of insulation. For example, although the floor area of the NAHB home is only 5 percent greater, the ceiling requiring insulation is 56 percent greater.

Characteristic	**Unit**	**PNNL**	**NAHB**	**Difference (%)**
Floor area	Square feet	2,376	2,500	5
Frame Wall	Square feet	2,000	2,675	34
Ceiling Insulation	Square feet	1,200	1,875	56
Slab Insulation	Linear Feet	140	200	43
Source: NAHB specifications are from their Cost Effectiveness Report. PNNL estimates (except floor area) were derived by dividing total cost by unit cost.				

The profit assumption combined with the design of the home would lead to cost estimates approximately 2.2 larger than the PNNL analysis.

[155] HUD expects that builder profits would diminish rather than increase from this regulation. The NAHB implies the reverse: that the increase in revenue is greater will be greater than the cost. It is more likely that profit rates will fall.

Appendix E: Algebra of Cost Incidence

Market equilibrium is defined as quantity demanded equaling quantity supplied given the price paid by buyers and received by producers:

$$Q^d\left(p^d\right) = Q^s(p^s)$$

The difference between the price of demand and price of supply is the incremental cost imposed by the regulation, c:

$$p^d = p^s + c$$

Changing the cost will drive a wedge between the price of demand and supply:

$$\Delta p^d = \Delta p^s + \Delta c$$

The change in the price paid by consumers is equal to the sum of the price received by suppliers plus the incremental cost. The change in price is determined by the properties of supply and demand:

$$\frac{\Delta Q^d\left(p^d\right)}{\Delta p^d} \cdot \Delta p^d = \frac{\Delta Q^s(p^s)}{\Delta p^s} \cdot \Delta p^s$$

Substitute the change in the price of demand in the right-hand side of the equation to get:

$$\frac{\Delta Q^d\left(p^d\right)}{\Delta p^d} \cdot \Delta p^d = \frac{\Delta Q^s(p^s)}{\Delta p^s} \cdot \left(\Delta p^d - \Delta c\right)$$

Rearranging and substituting the definition of the price elasticity of supply and demand yields an expression of the price paid by consumers:

$$\Delta p^d = \left(\frac{E_p^s}{E_p^s - E_p^d}\right) \cdot \Delta c$$

For greater price elasticities of demand and supply, consumers pay a larger portion of the price. To determine the percentage impact of the cost, start with the expression:

$$\frac{\Delta Q^d\left(p^d\right)}{Q^d} = E_p^d \cdot \frac{\Delta p^d}{p^d}$$

and substitute the expression for the change in the price of demand:

$$\frac{\Delta Q^d\left(p^d\right)}{Q^d} = \frac{E_p^d \cdot E_p^s}{E_p^s - E_p^d} \cdot \frac{\Delta c}{p^d}$$

Appendix F. Data Used to Estimate Aggregate Impacts of IECC Update

Per Unit Present Value Effects

Square Footage Adjustments for Incremental Effects

	Government-managed	Privately managed Rental	Single-Family	Condo
PNNL Model (SQFT)	1,200	1,200	2,376	1,200
HUD Average (SQFT)	900	900	2,000	1,600
Ratio HUD/PNNL	0.75	0.75	0.842	1.33
Adjustment Factor (Ratio^0.33)	0.90	0.90	0.95	1.10

PV Energy Savings ($), 3% Discount Rate

	2009 to 2021 IECC				2018 to 2021 IECC			
	Govt	MF	SF	Condo	Govt	MF	SF	Condo
PNNL	6,400	6,400	15,200	6,400	3,100	3,100	4,200	3,100
HUD	5,760	5,760	14,440	7,040	2,790	2,790	3,990	3,410

PV Energy Savings ($), 7% Discount Rate

	2009 to 2021 IECC				2018 to 2021 IECC			
	Govt	MF	SF	Condo	Govt	MF	SF	Condo
PNNL	4,200	4,200	10,000	4,200	2,000	2,000	2,800	2,000
HUD	3,780	3,780	9,500	4,620	1,800	1,800	2,660	2,200

Incremental Costs ($)

	2009 to 2021 IECC				2018 to 2021 IECC			
	Govt	MF	SF	Condo	Govt	MF	SF	Condo
PNNL	2,300	2,300	5,300	2,300	1,300	1,300	2,400	1,300
HUD	2,070	2,070	5,035	2,530	1,170	1,170	2,280	1,430

Aggregate Present Value Effects

Unit Counts: Annual New Construction in a Typical Year

Incremental Change	Govt-managed Rental	Privately managed Rental	Single Family	FHA Condos	Total
2009 to 2021 IECC	5,600	10,600	82,100	900	99,100
2018 to 2021 IECC	1,000	10,000	39,500	600	51,200
Total	6,600	20,700	121,600	1,500	150,300

PV Aggregate Energy Saving, 3% Discount Rate

Incremental Change	Govt	MF	SF	Condo	Total
2009 to 2021 IECC	32,256,000	61,056,000	1,185,524,000	6,336,000	1,285,172,000
2018 to 2021 IECC	2,790,000	27,900,000	157,605,000	2,046,000	190,341,000
Total	35,046,000	88,956,000	1,343,129,000	8,382,000	1,475,513,000

PV Aggregate Energy Saving, 7% Discount Rate

Incremental Change	Govt	MF	SF	Condo	Total
2009 to 2021 IECC	21,168,000	40,068,000	779,950,000	4,158,000	845,344,000
2018 to 2021 IECC	1,800,000	18,000,000	105,070,000	1,320,000	126,190,000
Total	22,968,000	58,068,000	885,020,000	5,478,000	971,534,000

Aggregate Upfront Incremental Costs

Incremental Change	Govt	MF	SF	Condo	Total
2009 to 2021 IECC	11,592,000	21,942,000	413,373,500	2,277,000	449,184,500
2018 to 2021 IECC	1,170,000	11,700,000	90,060,000	858,000	103,788,000
Total	12,762,000	33,642,000	503,433,500	3,135,000	552,972,500

Appendix G. Market Failure Scenarios for IECC Energy Codes

The review of the empirics and theory of residential energy efficiency investment raises the possibility that the paradox of unexploited private economic benefits may stem from an incorrect estimate of the benefits and costs. While there are reasons that market incentives would not necessarily lead to optimality of energy-efficient investment, there are also substantive motivations to invest optimally. Owners and landlords minimize the lifecycle costs of energy (taking account of upfront costs of energy efficiency measures), and developers could maximize their profits by building and selling an energy-efficient building. In an ideal world, where there is transparency, complete information, and no transaction costs, the marginal benefits from investment would equal the marginal costs.[156] Expressed another way, the marginal product of energy saving capital would equal the opportunity cost of capital.

To capture the possibility that all profitable investments have been pursued, we allow investors' discount rates to vary beyond the requisite 3 and 7 percent to close the gap between marginal benefits and costs. Applying the internal rate of return, which is the discount rate at which the NPV of a project equals zero, allows us to contrast optimality with market failures. The IRR approach is consistent with some of the earlier research on energy for which an implicit discount rate was estimated based on the upfront incremental cost and resulting stream of incremental benefits. The advantage of this approach is that we can continue to rely on the technical estimates of PNNL but also provide scenarios for which surplus internal energy savings are not be achieved.

We organize the analysis of properties by type of management with the belief that inefficiency will vary by the inherent economic incentives. Construction of rental units managed by a local government are likely to have a different set of incentives than rental units managed privately. Owner-occupiers internalize all costs and so may be less likely to choose a home with an inefficient design.

Discount Rate Used for Market Failure Scenarios

Scenario	Optimality of Energy Efficiency (NPV = 0)	Government-managed Rental	Privately managed Rental	Owner-occupied
Scenario 0	Govt, Private Rental, and Owned	14.05	13.75	11.71
Scenario 1	Private Rental and Owned	3 or 7	13.75	11.71
Scenario 2	Owned only	3 or 7	3 or 7	11.71
Scenario 3	No sectors	3 or 7	3 or 7	3 or 7

Notes: See Figure 3 for a description of the sources of energy inefficiency.

We calculate the internal rate of return for different types of assisted housing. Government-managed units includes those for which either the operation or construction is managed by the federal or a local government. The IRR for government-managed housing is approximately 14.1 percent. Privately managed rental units include FHA-insured multifamily rental units, for which HUD's only involvement is the insurance of the loan. The IRR for privately managed rental is 13.75 percent. Owner-occupied housing includes FHA-insured single-family (including condos) and USDA-guaranteed single-family housing. The IRR for owner-occupied energy efficiency is 11.71. All of these internal rates of return (above 10 percent) indicate that the present value of the energy-efficient investment will create private

[156] Assuming that marginal benefits are diminishing and marginal costs increasing.

gains at the discount rates of 3 or 7 percent. The energy paradox is present when the discount rate is below the internal rate of return.

In Scenario 0, all properties are efficiently built and managed and incentives are such that there are no energy inefficiencies. In Scenario 1, we allow for energy efficiency gains beyond marginal costs for government-owned and managed housing. In Scenario 2, we include rental housing in the total of internal energy efficiency gains. In Scenario 3, the upper most estimate, we include estimates for energy efficiency gains for all housing including owner-occupied housing.

When modelling annual and annualized effects, a higher discount rate raises costs relative to benefits and captures the economic opportunity costs of energy efficiency. Annual energy efficiency benefits do not change with a different discount rate because they are constant over time.

Annual Incremental Effects of One Cohort of Update to IECC 2021 ($)

Scenario	Annual Energy Savings	Annualized Costs (over 30 years at 3% or IRR)	Annualized Costs (over 30 years at 7% or IRR)
Scenario 0	73,087,000	73,087,000	73,087,000
Scenario 1	73,087,000	71,983,000	72,312,000
Scenario 2	73,087,000	69,243,000	70,440,000
Scenario 3	73,087,000	27,390,000	41,647,000

Given the large amount of owner-occupied new construction (FHA-insured single family, condos, and USDA-guaranteed loans), the private energy efficiency gains would not be significant without the assumption of a market failure in owned properties. This scenario may be the least likely because owners have a direct financial interest in the viability of their homes.

When applied to the present value analysis, a higher discount rate reduces benefits. In the present value analysis, a higher discount rate may capture some of the risk from energy price fluctuations or uncertainty concerning resale value.

Present Value of Incremental Effects Over 30 Years of Update to IECC 2021 for One Cohort ($)

Scenario	Upfront Costs	Energy Savings over 30 Years at 3% or IRR	Energy Savings over Years at 7% or IRR
Scenario 0	552,972,500	552,972,500	552,972,500
Scenario 1	552,972,500	575,256,500	563,178,500
Scenario 2	552,972,500	630,570,500	587,604,500
Scenario 3	552,972,500	1,475,513,000	971,534,000

As the breakeven condition is removed, the present value of energy saved climbs to $1.48 billion (3 percent discount rate) and $972 million (7 percent discount rate).

Appendix H. Social Cost of CO_2 Emissions

Annual SC-CO_2, 2020 – 2050 (in 2020 dollars per metric ton of CO_2) by Discount Rate and Scenario

	Average Scenario			High-Impact (95th Percentile)
	Discount rates			
Year of Emission	5%	3%	2.5%	3%
2020	14	51	76	152
2021	15	52	78	155
2022	15	53	79	159
2023	16	54	80	162
2024	16	55	82	166
2025	17	56	83	169
2026	17	57	84	173
2027	18	59	86	176
2028	18	60	87	180
2029	19	61	88	183
2030	19	62	89	187
2031	20	63	91	191
2032	21	64	92	194
2033	21	65	94	198
2034	22	66	95	202
2035	22	67	96	206
2036	23	69	98	210
2037	23	70	99	213
2038	24	71	100	217
2039	25	72	102	221
2040	25	73	103	225
2041	26	74	104	228
2042	26	75	106	232
2043	27	77	107	235
2044	28	78	108	239
2045	28	79	110	242
2046	29	80	111	246
2047	30	81	112	249
2048	30	82	114	253
2049	31	84	115	256
2050	32	85	116	260

Source: Table A-1, https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

Appendix I: Cash Flow Analysis by Climate Zone

Cash Flow for IECC 2009 to IECC 2021 for Average PNNL Unit by Climate Zone (interest rate of 5%)

Changes	**National**	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
Construction Cost	4,450	2,440	3,570	5,040	4,930	4,600	4,110	5,620	6,160
Upfront Loan Costs	339	186	271	384	376	350	313	428	469
Periodic Costs	363	199	290	411	402	375	335	458	502
Periodic Benefits	603	411	414	617	712	649	890	1,190	1,690
Net Periodic Benefits	240	212	124	206	310	274	555	732	1,188
Discounted Cumulative Cash Flow (discounted at 3 percent)									
By First Year	(98)	26	(148)	(178)	(66)	(76)	242	303	716
By Second Year	136	231	(28)	22	235	191	781	1,010	1,870
By Third Year	363	431	89	217	527	450	1,300	1,700	2,980
By Fourth Year	810	825	318	599	1,100	961	2,330	3,060	5,180
By Fifth Year	1,020	1,010	428	782	1,380	1,200	2,830	3,710	6,240

HUD Assumptions: Down payment 5%, upfront mortgage premium 1.75%, closing costs of 1 percent, annual interest rate 5%, mortgage lifetime 30 years, annual mortgage premium 0.8%, real energy price growth 0%, property tax rate 1.5%, consumer discount rate 3%

Cash Flow for IECC 2018 to IECC 2021 for Average PNNL Unit by Climate Zone (interest rate of 5%)

Change	**National**	**CZ1**	**CZ2**	**CZ3**	**CZ4**	**CZ5**	**CZ6**	**CZ7**	**CZ8**
Construction Cost	2,010	935	1,400	1,630	2,960	2,860	1,350	2,850	2,850
Upfront Loan Costs	153	71	107	124	225	218	103	217	217
Periodic Costs	164	76	114	133	241	233	110	232	232
Periodic Benefits	191	200	192	200	205	173	123	306	411
Net Periodic Benefits	27	124	78	67	(36)	(60)	13	74	179
Discounted Cumulative Cash Flow (discounted at 3 percent)									
By First Year	(126)	53	(29)	(57)	(261)	(278)	(90)	(143)	(39)
By Second Year	(100)	173	47	8	(295)	(336)	(77)	(72)	135
By Third Year	(75)	290	121	71	(329)	(393)	(65)	(2)	303
By Fourth Year	(25)	520	266	196	(396)	(505)	(40)	134	635
By Fifth Year	(0)	630	335	255	(427)	(558)	(29)	200	794

HUD Assumptions: Down payment 5%, upfront mortgage premium 1.75%, closing costs of 1 percent, annual interest rate 5%, mortgage lifetime 30 years, annual mortgage premium 0.8%, real energy price growth 0%, property tax rate 1.5%, consumer discount rate 3%