Director Orlene Hawks
Michigan Department of Licensing and Regulatory Affairs
611 W. Ottawa Street
Lansing, MI 48933

Dear Director Hawks,

I am the President of Vander Meulen Builders, a 4th generation residential building company based in Holland, Michigan. I am certified from the NAHB as a CAPS (Certified Aging in Place Specialist) contractor, have taken multiple classes on Advanced Building practices, and was part of the NAHB POG (proposal oversight group) for the 2021 IECC Energy Code. I am writing to convey my comments, concerns and a couple of questions relative to the promulgation of Part 10 Michigan Uniform Energy Code rules, 2021-48 LR by your department.

I oppose the unilateral implementation of the 2021 International Energy Conversation Code (IECC) in our state. Historically, our state has used model codes developed by the International Code Council (ICC) as the starting point for code changes, amending such to conform with our state law and other Michigan-specific needs. Your department is, perhaps, overlooking these important facts in moving this rule set forward. Further, this action fails to recognize the Michigan housing affordability/ attainability housing crisis. The cost of building a typical Michigan home has doubled in price over the past five years. The proposed energy code changes your department is considering, if applied to residential construction, would add several thousand dollars in additional costs for new homes. We know that for every thousand-dollar increase in home construction costs, nearly 5,300 households in our state are priced out of being able to afford it. If this rule set is adopted without amendment and is applied to residential housing, fewer people will be able to afford more energy efficient homes.

Furthermore, A significant part of my business involves renovations of existing structures. While I am supportive of making cost effective upgrades during these projects, I am concerned that meeting the requirements proposed will be an onerous burden for many projects and will result in these projects not being performed, leading to a decline in revenue.

Lastly, I currently work with a number of jurisdictions for my projects. There are 8-10 building officials that I work with regularly, each of which has their own interpretations of the building an energy code, and I am terrified that the proposed regulations are going to further complicate the permitting, building, and inspection processes during construction, adding significant time and expense to each project.

In terms of following state law, the issuance of the Regulatory Impact Statement and Cost Benefit Analysis (RIS) for the Part 10 Michigan Uniform Energy Code rules, 2021-48 LR raised significant questions for me and others in our industry. For those top energy efficiency contractors in our marketplace, these two questions need to be answered by your department before further action is taken:

1. Will national, state or local energy efficiency programs evaluated and approved by the State Construction Code Commission as exceeding the energy efficiency required by the proposed code be considered in compliance with the proposed rules?
2. What is the process for a program to apply for approval? What is the process for the State Construction Code Commission to evaluate and approve these programs?

Thank you for the consideration of my comments and questions.

Sincerely,

Aaron Vander Meulen
President

Submitted via Email: LARA-BCC-Rules@michigan.gov

July 5, 2022

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Administrative Services Division

American Chemistry Council Comments Supporting the Michigan Adoption of the 2021 International Energy Conservation Code for Residential and Commercial Buildings

The American Chemistry Council (ACC) thanks you for the opportunity to submit comments and recommend the adoption of the 2021 International Energy Conservation Code (IECC) with reference to ASHRAE 90.1-2019.

Chemistry is essential to the U.S. economy and plays a vital role in driving innovations that make our world safer, more sustainable, and more productive. Chemistry supports over 25% of the U.S. GDP and 9% of U.S. goods exports – a $486 billion enterprise. 529,000 skilled American jobs are provided by the business of chemistry. The U.S. is the 2nd largest global producer, providing 13% of the world's chemicals. Chemistry in Michigan pays $1.83 billion in wages and generates $138 million in state and local taxes.[1]

There are many reasons we support the Michigan adoption of these modern energy codes. Primarily, the energy savings that are realized by the people who live and own businesses in the state. The Department of Energy (DOE) determined the 2021 energy codes provide **cost-effective levels of energy efficiency** and performance for residential and commercial buildings in Michigan. Based on housing starts in Michigan the adoption of the 2021 Residential IECC would save $3,873,000 in the first year alone.[2] Likewise, based on new commercial construction numbers in Michigan the adoption of the 2021 IECC with reference to ASHRAE 90.1-2019 for commercial buildings would save $1,587,000 in the first year alone.[3]

This is especially important in order to address the **environmental justice issue of the affordable housing** needs of lower income households. According to the U.S. Energy Information Administration:

[1] See Michigan.pdf (americanchemistry.com)

[2] See Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan (energycodes.gov)

[3] See Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Michigan (energycodes.gov)

Across the United States, high utility bills are costing homeowners a significant portion of their monthly incomes. According to the most recent EIA Residential Energy Consumption Survey,[4] about one in five households reported reducing or forgoing basic necessities like food and medicine to pay an energy bill. Stronger energy codes and more widespread code compliance can help change the tide on this type of energy poverty. Improving compliance with residential energy codes opens up an array of economic and health benefits for homeowners, residents, local governments, and building officials, including:

- Reduced energy costs that yield monthly savings for owners and occupants, helping to boost the local economy and improving housing affordability by reducing utility costs.
- More comfortable and durable homes that better shield people from outdoor temperature extremes.
- Better protected occupant health from improved efficiency and indoor air quality.
- Greater market certainty for the building design and construction industry due to consistent implementation across jurisdictions.
- A level playing field for manufacturers, builders, and other building related industries.

Beyond the obvious energy savings benefits there are many other important reasons for Michigan to update their building energy codes:

- **Job creation,** based on U.S. Census data on residential housing permits, it is estimated that over 80,000 residential one- and two-family homes have been permitted in Michigan since the last energy code update in late 2017.[5]
- **GHG emission reductions,** DOE estimates that the 30-year cumulative reduction of CO_2 emissions that Michigan would realize with the adoption of the 2021 residential provisions is equivalent to 11,460,000 metric tons.[6]
- **Resilience,** in a 2021 report the National Institute of Building Sciences found that adopting the latest building code requirements is affordable and saves $11 per $1 invested. Building codes have greatly improved society's disaster resilience, while adding only about 1% to construction costs relative to 1990 standards. The greatest benefits accrue to communities using the most recent code editions.[7]
- **Energy Security,** the International Energy Agency recognizes that energy efficiency can bolster regional or national energy security. By reducing overall energy demand, efficiency can reduce

[4] See Residential Energy Consumption Survey (RECS) - Energy Information Administration (eia.gov)
[5] See U.S. Census Bureau, Building Permits Survey, available at https://www.census.gov/construction/bps/
[6] See Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan (energycodes.gov)
[7] See Mitigation Saves: Mitigation Saves up to $13 per $1 Invested (nibs.org)

reliance on imports of oil, gas and coal. Energy efficiency can therefore play a crucial role in ensuring both long- and short-term energy security in a cost-effective manner.[8]

ACC is grateful for the opportunity to encourage and support the adoption of the 2021 International Energy Conservation Code (IECC) for all the great benefits these new codes would bring to the people in the State of Michigan.

Sincerely,

Amy Q. Schmidt

Amy Schmidt
American Chemistry Council
Director, Building and Construction

[8] See Energy security – Multiple Benefits of Energy Efficiency – Analysis - IEA

Lombardo
H • O • M • E • S

Over 50 Years of Excellence

June 30, 2022

Department of Licensing and Regulatory Affairs
Attn: Amanda Johnson – Rules Analyst
611 W. Ottawa Street
Lansing, MI 48933
Via email: LARA-BCC-Rules@michigan.gov

Please accept this letter as comment in response to the "Notice of Public Hearing" from the Department of Licensing and Regulatory Affairs, Bureau of Construction Codes related to Rule Set 2021-48 LR. I am opposed to the adoption of the 2021 International Energy Conservation Code (IECC) in Michigan.

Lombardo Homes was founded more than 60 years ago as a company specializing in attached and courtyard condominiums in Michigan. Today, Lombardo Homes operates in multiple states building apartments, single family homes, and attached condominiums. The Lombardo portfolio includes Cranbrook Custom Homes, luxury custom homes; Lombardo Homes of Michigan, semi-custom production homes; Lombardo Homes of St. Louis, luxury custom homes; Lombardo Homes of Columbia, luxury custom homes in Columbia/Ashland, Missouri; Lombardo Apartments STL, luxury apartments in Missouri and Illinois; and Lombardo Apartments MI, luxury apartments in southeast Michigan.

Michigan is already facing a housing affordability crisis – a crisis which will be deepened if the proposed rules are approved. This crisis is especially acute for entry level buyers, who are extremely price sensitive. Many of these buyers are the foundation of Michigan's workforce. They are first responders, teachers, manufacturing workers and governmental officials. Government regulations such as this proposal, which unnecessarily drive up the cost of housing, will price these important Michigan workers and their families out of the ability to purchase new housing.

Furthermore, the high upfront costs associated with 2021 IECC are not offset by energy savings which result in reasonable payback periods as required by state law. Studies by experts, such as Home Innovation Research Labs and others, show payback periods which are decades long. Our internal research at Lombardo Homes shows the implementation of this code would add well over $10,000 in upfront costs to our home plans. Ultimately the upfront costs of these measures would be counterproductive as these costs will keep people in older, less energy efficient housing.

I acknowledge this initiative and understand the importance of continual movement toward more energy efficient homes. However, I encourage this proposed initiative be broken into detailed phases and adopted gradually, over a span of years.

Lombardo
H • O • M • E • S

Over *50 Years* of Excellence

In addition to consideration of my comments above, I ask the Department of Licensing and Regulatory Affairs to provide further clarity to the industry by answering, in writing, the following question:

> Do the proposed rules apply to 1- and 2-family dwellings and townhouses not more than 3 stories above grade plane in height with a separate means of egress and their accessory structures?

Sincerely,

Anthony Lombardo
CEO

ROBERTSON BROTHERS HOMES

July 1, 2022

Department of Licensing and Regulatory Affairs
Attn: Amanda Johnson – Rules Analyst
611 W. Ottawa Street
Lansing, MI 48933
Via email: LARA-BCC-Rules@michigan.gov

In response to the "Notice of Public Hearing" from the Department of Licensing and Regulatory Affairs (LARA), Bureau of Construction Codes, please accept this written comment related to Rule Set 2021-48 LR. Robertson Homes is opposed to the changes as proposed by LARA for Part 10 of the Construction Code.

Robertson Homes is a local homebuilder and developer that has been developing communities in Southeastern Michigan for over 75 years. We develop and build approximately 200 homes per year. While we do build luxury communities, recently we have been focusing on dense, infill missing middle housing options. That market is very sensitive to cost as this product is often a starter home for the young professionals and workforce resident demographics that are trying to get in the game and build equity. This demographic is often moving from either an older apartment or decades old home with a fraction of the efficiencies of a modern home. If the costs of new construction get too high, then this demographic cannot afford new construction and are forced to remain in apartments or homes built decades ago that are nowhere near as efficient as modern homes built under the current Michigan energy code. Forcing residents to remain in older, less efficient housing stock feels counter-productive to what we are trying to accomplish in our industry at both a national and state and local level.

Michigan's economy would be irreparably harmed by adoption of these rules as proposed because the provisions of the 2021 IECC will significantly increase the cost of constructing homes in Michigan. This will put our state at a disadvantage when trying to attract new businesses and residents, and will exacerbate the shortage of attainable homes for our existing residents. In contrast, Michigan's current energy code provides for an appropriate standard which balances the upfront costs of energy efficiency with the payback to the public in energy savings.

An additional concern we have is the lack of clarity and public discussion on the full impact of the proposed rules. Previously, potential changes to Michigan's energy code provisions were discussed and debated openly among a diverse group of industry experts. For this code proposal, who made the decision to move forward with the 2021 IECC? What expertise does that person(s) have to understand the impact of this change and its interaction with the rest of Michigan's construction codes?

6905 Telegraph Road, Suite 200, Bloomfield Hills, MI 48301
phone (248) 644.3460 www.RobertsonHomes.com

Another specific question we have is do the proposed rules apply to live/work units complying with the requirements of Section 419 of the Michigan Building Code being built as 1- and 2-family dwellings or townhouses under the Michigan Residential Code?

I look forward to LARA's public response to these questions, and to its review of housing affordability issues as it considers this significant code change.

Sincerely,

Darian Neubecker
COO

D.R. Nelson & Associates

Building Science Delivered

July 5, 2022

Department of Licensing and Regulatory Affairs - Bureau of Construction Services

Re: Public hearing on amendments for the Michigan Energy Code.

For more than 40 years my company has advocated for cost-effective products and services.
I have served as a paid Subject Matter Expert for the International Code Council on energy codes. Our company competes in the marketplace, providing sensible services to builders in the design, construction, and sales of cost-effective, energy efficient and environmentally sustainable homes. We serve more than 100 Michigan home builders.

It is my belief the 2021 IECC as written was significantly influenced by the North American Insulation Manufacturers Association (NAIMA). This is reflected in the fact of the removal of credits for the use of high efficiency furnace, air conditioning or water heating and that there is little opportunity for credit in reduced air leakage as that requirement is unrealistically low (3ACH@50Pa). Clearly the emphasis on this code is increasing R-value.

Building Science research is very clear – once minimum levels of insulation are achieved an emphasis on R-value alone does very little to impact efficiency of homes and reduce carbon footprint. Insulation levels have increased significantly over the past 10 years, and to achieve impactful reductions in carbon footprint, fuel use, and operating expenses we need to look at the mechanical system of the home.

The mechanical system is an extremely significant factor into the energy consumption of a home. The code as written allows for an 80% gas furnace. That means for every 100 units of energy coming into the home only 80 units are available for operation.

We used Department of Energy approved software for construction modeling (REM/Rate) to compare the changes in the 2021 IECC (what I call the "R-Value approach") to simply installing a higher efficiency furnace. We took three different size generic floorplans. Details can be found at the end of this document. What we found is the mechanical system approach is MORE impactful than the R-Value approach yet the 2021 IECC doesn't even address this!

R-VALUE APPROACH			
	1250sf Home	2150sf Home	3000sf Home
Foundation Insulation	$23.83	$16.67	$20.17
Exterior Wall Insulation	$29.17	$42.33	$51.17
Ceiling Insulation	$18.00	$19.00	$18.00
Window U-Value	$7.00	$9.00	$27.00
TOTAL Yearly Savings	**$78.00**	**$87.00**	**$116.34**
Reduction in CO2 emissions:	(-0.6)	(-0.8)	(-1.0)

MECHANICAL APPROACH			
	1250sf Home	2150sf Home	3000sf Home
96% Furnace Yearly Savings	**$102.00**	**$111.00**	**$160.00**
Reduction in CO2 emissions:	(-0.7)	(-0.8)	(-1.3)

The impact of the 2021 MEC will be hardest for entry level home buyers. The incremental energy savings from adopting the 2021 IECC will not offset the increased construction costs even if current home energy costs double or triple. This will result in people remaining in older and much less energy efficient homes (with a higher carbon footprint) than those built under the current 2015 MEC.

I believe that adoption of the 2021 International Energy Conservation Code at this time will significantly increase house construction costs forcing many people out of the new home market. Affordability is an issue today – there are much more cost-effective ways to reduce carbon footprint, lower emissions, reduce fuel use, while also keeping costs down.

We want affordable, fuel efficient, reduced carbon footprint homes. 40 years ago, we saw a need for cost effectively improving performance of new construction homes. We think this code significantly misses the mark in that regard. R-value alone is not the answer. Flexibility and incentivizing builders to address total home performance, instead of the amount of insulation only is imperative.

At a minimum we propose keeping section N1101.7 (R102.1.1) of the 2015 MRC:

> **R102.1.1 Above code programs.** The state construction code commission may evaluate and approve a national, state or local energy efficiency program to exceed the energy efficiency required by this code. Buildings approved in writing by such an energy efficiency program, such as ICC 700-2012 "silver" or energy star version 3 (rev. 07) shall be considered in compliance with this code. The requirements identified as "mandatory" in chapter shall be met.

This will allow some flexibility (construction cost savings) for builders to exceed the intention of this code.

Respectfully submitted,

Don Nelson

R-VALUE APPROACH

Prescriptive Table				
MODEL	**Foundation**	**Ceilings**	**Framed Walls**	**Windows**
2015 MRC	10ci, 13	38	20 or 13+5ci	0.32
2021 MEC	15ci, 19, or 13+5ci	60	20+5ci, 13+10ci, or 15ci	0.3

FOUNDATION (annual energy savings)						
MODEL	**R-10ci to R-15ci**	**R-10ci to R-19**	**R-10ci to R-13+5ci**	**R-13 to R-15ci**	**R-13 to R-19**	**R-13 to R-13+5ci**
1250sf	$29	$4	$22	$40	$15	$33
2150sf	$22	$4	$17	$20	$12	$25
3000sf	$24	$4	$19	$33	$13	$28

FRAMED WALLS (annual energy savings)						
MODEL	**R-20 to R-20+5ci**	**R-20 to R-13+10ci**	**R-20 to R-15ci**	**R-13+5ci to R-20+5ci**	**R-13+5ci to R-13+10ci**	**R-13+5ci to R-15ci**
1250sf	$37	$40	$22	$29	$32	$15
2150sf	$54	$58	$33	$42	$46	$21
3000sf	$65	$70	$41	$50	$55	$26

CEILINGS (annual energy savings)	
MODEL	**R-38 to R-60**
1250sf	$18
2150sf	$19
3000sf	$18

WINDOWS (annual energy savings)	
MODEL	**0.32 to 0.30**
1250sf	$7
2150sf	$9
3000sf	$27

SUMMARY

R-VALUE APPROACH			
	1250sf Home	2150sf Home	3000sf Home
Foundation Insulation	$23.83	$16.67	$20.17
Exterior Wall Insulation	$29.17	$42.33	$51.17
Ceiling Insulation	$18.00	$19.00	$18.00
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TOTAL Yearly Savings	**$78.00**	**$87.00**	**$116.34**
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MECHANICAL APPROACH			
	1250sf Home	2150sf Home	3000sf Home
96% Furnace Yearly Savings	**$102.00**	**$111.00**	**$160.00**
Reduction in CO2 emissions:	(-0.7)	(-0.8)	(-1.3)

Comparison of 2021 IECC Residential Cost Effectiveness Analyses

This document is intended to provide a comparison of two reports the *2021 IECC Residential Cost Effectiveness Analysis* published for the National Association of Homebuilders (NAHB) by Home Innovation Research Labs (HIRL) in June 2021, hereafter referred to as the HIRL report[1]; and the report of the same name published by ICF in January 2022, hereafter referred to as the ICF report. The purpose of this document is to identify concerns and issues in the HIRL report, which were addressed in the ICF report.

Simplistic Economic Metrics

The HIRL report only evaluates cost effectiveness using a simple payback metric, which is easy to calculate and understand, however it is not appropriate to use for evaluating energy code changes. The U.S. Department of Energy's *Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes* (DOE Methodology)[2] concludes that "because simple payback ignores many of the longer-term factors in the economic performance of an energy-efficiency investment, DOE does not use [simple payback] as a primary indicator of cost effectiveness for its own decision-making purposes."

Instead, the DOE Methodology uses Life-Cycle Cost (LCC) as the primary metric to evaluate cost effectiveness, therefore the ICF report also uses this metric.

High Builder Profit Margins

The HIRL report stated that the total cost to the consumer included a builder's gross profit margin of 19%. Several issues were found with this, all leading to higher costs which would negatively impact cost effectiveness.

First, many code changes in Appendix A of the HIRL report were found to have a higher profit margin applied. For example, RE112 had a reported cost to the builder of $200 and a cost to the consumer of $247, which would be a profit margin of 24%.

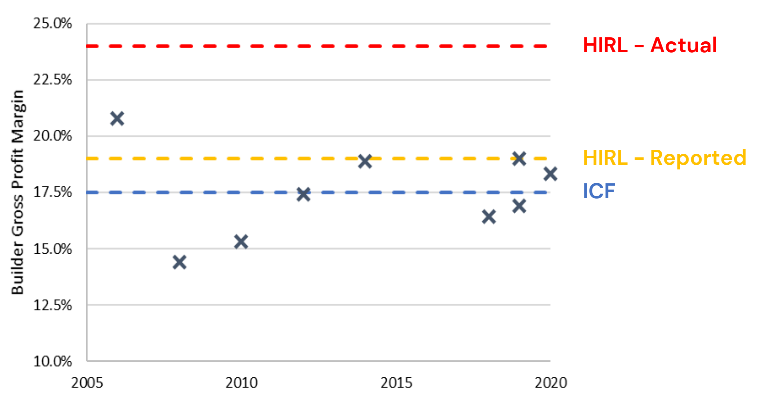

Figure 1: Comparison of Builder Gross Profit Margin

Additionally, the ICF report considered changes in builder profit margins over time and used an average value representing all data that was available. In figure 1, the data available for builder gross profit margin is shown by black X's, with their average – the value used in the ICF report - shown by the blue line. The profit margin used in the ICF report is a more representative value, as the value reported to have been used in the HIRL report is the highest profit margin seen since 2006, and the value that was actually used is higher than any reported historical profit margin.

Finally, the HIRL report assumed all construction was performed by subcontractors, so the excessively high profit margin of 24% was applied twice, once reflecting the subcontractor's profit and again to reflect the builder's profit. To reflect that the majority, but not all, aspects of homebuilding are subcontracted, the ICF report applied a factor of 79.3% to subcontractor markups to reflect the average share of construction costs that are subcontracted dating back to 2012.[3]

1 Source: https://www.nahb.org/-/media/NAHB/advocacy/docs/top-priorities/codes/code-adoption/2021-iecc-cost-effectiveness-analysis-hirl.pdf
2 Source: https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf
3 Source: https://www.nahb.org/-/media/NAHB/news-and-economics/docs/housing-economics-plus/special-studies/2020/special-study-average-new-home-uses-24-different-subcontractors.pdf

General High Cost

When reviewing the HIRL report, the high estimated incremental cost of code changes conflicted with other data sources, specifically Northwest national Laboratory's (PNNL's) *National Cost Effectiveness of the Residential Provisions of the 2021 IECC*, as shown in Figure 2.[4] After reviewing and updating cost data, the ICF report concluded costs were generally in line with the PNNL report, instead of 2 to 3 times higher as shown in the HIRL report.

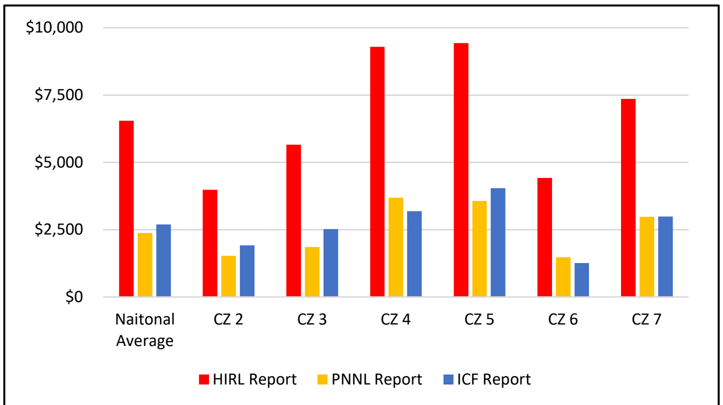

Figure 2: Comparison of 2021 IECC Code Change Costs

Costs for Negligible Administrative Changes

Some code changes in the 2021 IECC are administrative and technically are new requirements, but in practice require no, or negligible, incremental cost. They simply require reporting readily available information (e.g., RE18, 20, 21, CE40.2). The HIRL report included a cost of $114 for these code changes for every home, which was considered inaccurate and removed in the ICF report.

Costs Included for Code Changes that Save Energy but Not Modeled

Some code changes result in energy savings but were not able to be modeled due to limitations in energy modeling software. Therefore, energy savings for these changes are not included. Despite this limitation the HIRL report included costs for these code changes leading to an inaccurate accounting of costs and calculation of cost-effectiveness. These code changes include RE149 Lighting: exterior controls, and RE49 Baffles at attic access.

Outlier Energy Savings Estimates

Savings from the HIRL report and PNNL's savings estimates (*Energy Savings Analysis: 2021 IECC for Residential Buildings*[5]), were compared and national average savings were comparable (9.7% for HIRL and 8.7% for PNNL). However, some results in specific climate zones showed significant differences as shown in Figure 3 (i.e., climate zones 3 and 7). Due to the robustness of the methodology that PNNL's savings estimates used, it is likely that there is an issue with the modeled energy use in the HIRL report. However, this cannot be confirmed, nor could the potential impact on the cost-effectiveness be determined.

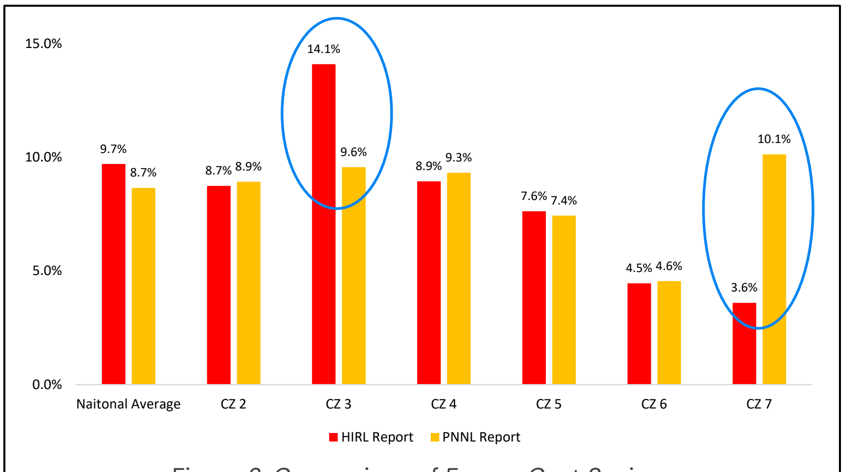

Figure 3: Comparison of Energy Cost Savings

Weighting Factors & Permutations

The HIRL report relies on a methodology developed in 2012 for the National Association of Homebuilders.[6] This methodology is notably simpler than the DOE methodology, last updated in 2015 based on a public process where stakeholders can submit comments on the methodology.[7] The methodology used in the

[4] Source: https://www.energycodes.gov/sites/default/files/2021-07/2021IECC_CostEffectiveness_Final_Residential.pdf
[5] Source: https://www.energycodes.gov/sites/default/files/2021-07/2021_IECC_Final_Determination_AnalysisTSD.pdf
[6] Source: https://www.nahb.org/-/media/NAHB/advocacy/docs/top-priorities/codes/codes-and-research/calculation-methodology.PDF
[7] Source: https://www.regulations.gov/docket/EERE-2015-BT-BC-0001

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HIRL report has not been publicly vetted. It utilizes a smaller number of foundation types, fuel types, and locations than DOE uses to assess codes and leads to a less complete picture of the impacts of code changes.

The HIRL report also relies on weighting factors that differ from the DOE methodology. For example, the HIRL report uses data from the 2019 Annual Builder Performance Survey (ABPS) of approximately 1,500 home builders to estimate the amount of construction in each climate zone. The DOE methodology relies on the U.S. Census Builder Permits Survey which gathers permit data from over 20,000 permit offices. the Census data provides a larger statistical sample and presumably the better source for establishing weighted national averages.

Annual Energy Use / Costs Errors

Appendix E in the HIRL report presents annual energy use and costs for 153 modeled homes, 19 of which were identified as having a significant error where the reported energy use and energy rates did not result in the documented energy costs. See below for an example of the climate zone 7, crawlspace, 2018 IECC home which results in a discrepancy of over $40.

Reported Energy Use	Reported Energy Rates	Calculated Energy Cost	Reported Energy Cost
7,119 kWh 1,473 therms	$0.1301 / kWh $1.051 / therm	$2,474 (7,119 x 0.1301 + 1,473 x 1.051)	$2,515

To correct this issue, the ICF report applied a factor to correct the energy use to result in the reported energy cost. The reported energy cost could not have been used directly because the ICF report used a more robust economic metric which accounts for changes in future energy prices.

Dimmer Quantity Error

RE145 changes lighting requirements and adds lighting controls except for bathrooms, hallways, exterior lighting fixtures, and lighting designed for safety or security. The HIRL report includes a cost for a dimmer in a crawlspace, which would be an exempted for safety purposes. Including the crawlspace dimmer cost overstates the cost of the code change and negatively impacts cost-effectiveness, so the cost was removed in the ICF report.

Duct Option Analysis Omits Some Foundation Types

The HIRL report only considered slab and crawlspace homes for the more efficient thermal distribution system option (from RE209). This option could be used for any home and should have been evaluated for more foundation types (e.g., basements) to offer a complete picture of the savings and cost-effectiveness. For some foundation types, like conditioned basements, it is likely that ducts were already located in conditioned space before the 2021 IECC so there would be no change in requirements resulting from this code change.

Misleading Cost Effectiveness of Additional Efficiency Package Options

Table 21 in the HIRL report makes a misleading comparison of the cost-effectiveness of the additional efficiency package options against a baseline of the 2021 IECC (without the options). This is an odd comparison because the options, combined with the other code changes of the 2021 IECC, achieve savings against the 2018 IECC. Therefore the 2018 IECC would have been a more appropriate baseline and would show more savings and better cost-effectiveness. The table could be useful to make a comparison of which option is relatively more cost-effective, but should not be used to determine if these options are cost effective or not.

Cost Effectiveness of the Residential Provisions of the 2021 IECC

January 2022

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Background

The International Code Council (ICC) updates their model building codes on a 3-year cycle. The latest version of their International Energy Conservation Code (IECC) is the 2021 IECC[1] and contains multiple updates, or code changes, to the 2018 IECC as a result of a public process administered by the ICC.[2]

The code changes from the 2018 to the 2021 IECC result in both increased energy savings and construction costs, and this analysis quantifies the resulting cost-effectiveness.

Following U.S. Department of Energy cost effectiveness certification of the 2021 IECC, the National Association of Homebuilders (NAHB) commissioned the Home Innovation Research Labs (HIRL) to conduct an independent cost analysis of the 2021 IECC. The report, *2021 IECC Residential Cost Effectiveness Analysis*[3] (HIRL report), was published in June 2021, and asserted that the 2021 IECC imposed builder compliance costs of nearly $12,000 and homeowner payback periods of up to 79 years, depending on climate zone. This analysis is intended to "check the math" of the NAHB report using current cost data and widely accepted cost effectiveness metrics. To enable an easy comparison this report mirrors the HIRL Report structure, section by section and table by table, and is accompanied by a short comparison document titled Comparison of 2021 IECC Residential Cost Effectiveness Analyses, which also identifies concerns and issues identified in the HIRL report that were addressed.

Methodology

This analysis relies on existing data and new research. The primary source is the HIRL report mentioned above.

The energy savings for this analysis were sourced directly from the HIRL report and are documented in Appendix E. Below is how the HIRL report describes how energy savings were developed.

> "The analysis for this study is based on a methodology[4] developed by Home Innovation (formerly NAHB Research Center) to calculate energy savings. This methodology defined a Standard Reference House, including the building configuration and energy performance parameters, that was originally used to report an analysis of the 2012 IECC code changes.[5]
>
> For analysis in this report, annual energy use costs were developed using BEopt[6] 2.8.0.0 hourly simulation software and energy prices from the U.S. Energy Information Agency.[7] The energy prices are national average annual 2019 residential prices: $0.1301/kWh for electricity; $1.051/therm for natural gas."

The incremental costs of the code changes reported in the HIRL report were evaluated and updated. Material costs were generally updated to use publicly available sources from retailers and distributors, with sources shown in Appendix A. The majority of labor costs from the HIRL report were used and were developed using labor rates from RS Means.[8] Some code changes that contained a cost in the HIRL report were determined to result in no incremental cost after a review of the code change.

Cost-effectiveness was evaluated using the U.S. Department of Energy's *Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes* (DOE Methodology),[9] which is used when DOE conducts a determination analysis to evaluate whether the new edition of the IECC saves energy compared to its immediate predecessor. The HIRL report only considered simple payback, which is included in the DOE

1 https://codes.iccsafe.org/content/IECC2021P1
2 https://www.iccsafe.org/products-and-services/i-codes/code-development/
3 https://www.nahb.org/-/media/NAHB/advocacy/docs/top-priorities/codes/code-adoption/2021-iecc-cost-effectiveness-analysis-hirl.pdf
4 Methodology for Calculating Energy Use in Residential Buildings. NAHB Research Center, May 2012.
5 2012 IECC Cost Effectiveness Analysis. NAHB Research Center, May 24, 2012.
6 BEopt (Building Energy Optimization Tool) software: https://beopt.nrel.gov/home
7 Energy Information Agency: https://www.eia.gov/
8 https://www.rsmeans.com/
9 https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf

methodology along with Life-cycle cost, which was added for this analysis. A description of the two metrics used in this analysis are shown below, as described by the DOE methodology:

- Life-Cycle Cost (LCC) is a robust cost-benefit metric that sums the costs and benefits of a code change over a specified time period. Any code change resulting in a net LCC less than or equal to zero (i.e., monetary benefits exceed costs) will be considered cost effective. LCC is the primary metric DOE uses to evaluate cost-effectiveness.
- Simple payback period is a straightforward metric including only the costs and benefits directly related to the implementation of energy-saving measures associated with a code change. It represents the number of years required for the energy savings to pay for the cost of the measures, without regard for changes in fuel prices, tax effects, measure replacements, resale values, etc.

All costs and savings in this analysis are based on the model 2018 and 2021 IECC codes. When adopting codes many states and local jurisdictions implement amendments, often decreasing the stringency of codes. And as of January 2022, only 9 states (including Washington D.C.) have adopted a code equally stringent to the 2018 IECC.[10] Therefore for the remaining 42 states would realize greater energy savings, and likely be more cost-effective, than what is estimated in this analysis.

Standard Reference House

The building geometry in Table 1 utilized in this analysis is specified in the HIRL report and was originally for a representative single-family detached home using Home Innovation's 2009 Annual Builder Practices Survey (ABPS). The parameters are average values from the ABPS for non-IECC-mandated building areas and features. Based on Home Innovation's 2019 ABPS, the geometry was revised. The floor, attic, wall, and window areas used in the Standard Reference House for this study are shown in Table 1.

Table 1 Average Wall and Floor Areas of the Reference House

Reference House Component	Area (SF)
1st floor conditioned floor area (CFA)	1,875
2nd floor CFA	625
Total CFA without conditioned basement	2,500
Foundation perimeter, linear feet (LF)	200
Slab/basement/crawl floor area	1,875
Total CFA with conditioned basement	4,375
Ceiling area adjacent to vented attic	1,875
1st floor gross wall area (9' height)	1,800
2nd floor gross wall area (8.75' height)	875
Total above grade wall area (excludes rim areas)	2,675
Basement wall area (8' height; 2' above grade)	1,600
Crawlspace wall area (4' height; 2' above grade)	800
Window area (15% of CFA above grade)	375

[10] Source: https://www.energycodes.gov/status/residential

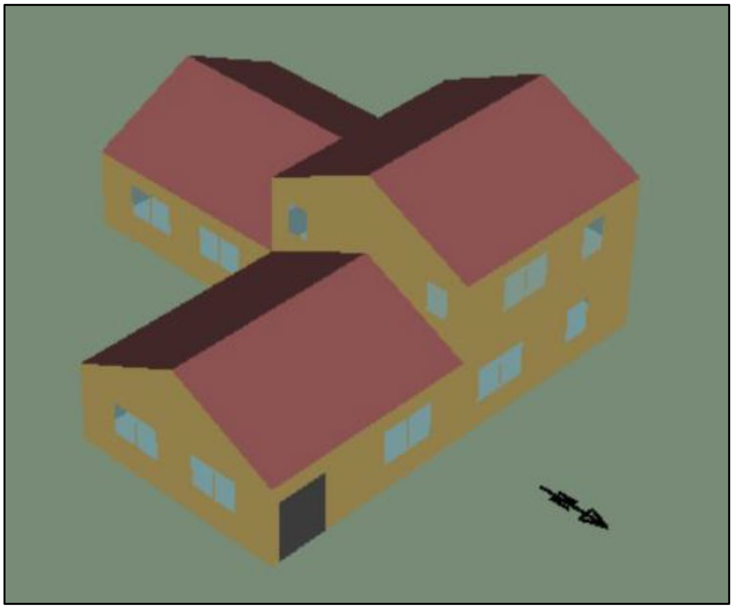

Figure 1 Simulation Model of Standard Reference House

Representative Locations

Energy savings were quantified using six representative locations in climate zones (CZs) 2 through 7, as shown in Table 2.

Table 2 Representative Locations

Climate Zone	2	3	4	5	6	7
City	Phoenix	Memphis	Baltimore	Chicago	Helena	Duluth
State	Arizona	Tennessee	Maryland	Illinois	Montana	Minnesota
Moisture Region	Dry	Moist	Moist	Moist	Dry	n/a
HDD65*	1,050	2,960	4,600	6,330	7,660	9,570
CDD65*	4,640	2,110	1,233	842	317	162
*Daily Average Weather Data (TMY). Source: Residential Energy Dynamics, redcalc.com						

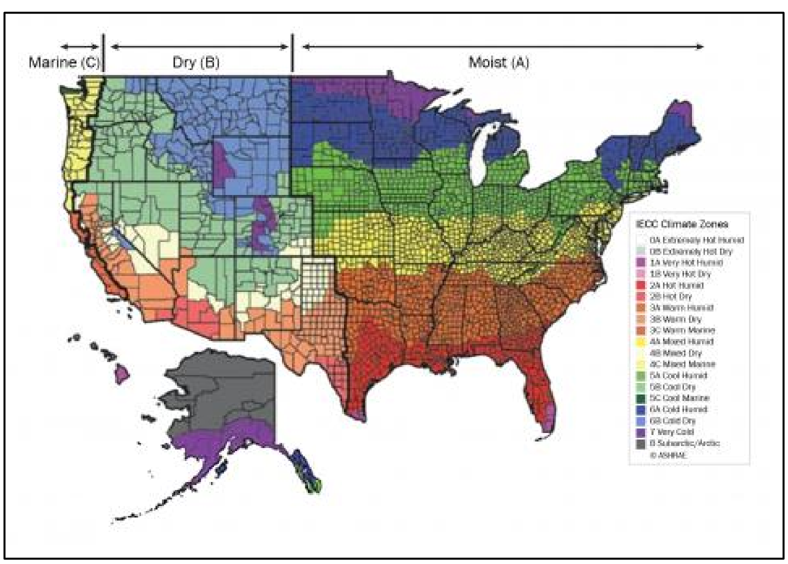

Figure 2 DOE Climate Zone Map

Configurations and Weighted Averaging

Results in this analysis (e.g., costs, savings, economic metrics) have been weighted by wall type, foundation type, for each climate zone, and by each location to result in a national weighted average. The data in Table 3 was used for these weightings and is based on the 2019 ABPS.

Only one heating fuel was used for each location based on the predominant fuel in the climate, and the heating and domestic hot water equipment use the same fuel.

Table 3 Construction Data. Source: adapted from Home Innovation's 2019 ABPS

Climate Zone	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
Primary Heating Fuel	Electric	Electric	Gas	Gas	Gas	Gas
Mass Wall	30%	10%	n/a	n/a	n/a	n/a
Frame Wall	70%	90%	100%	100%	100%	100%
Slab	100%	75%	20%	15%	5%	30%
Cond. Basement	n/a	10%	60%	70%	90%	5%
Vented Crawlspace	n/a	15%	20%	n/a	n/a	n/a
Cond. Crawlspace	n/a	n/a	n/a	15%	5%	65%
Housing Starts	28%	28%	21%	17%	5%	1%

HVAC and Water Heating Equipment

The refence house is configured with equipment meeting the current DOE energy-efficiency standards as shown in Table 4. When an 'additional efficiency package option' from the 2021 IECC would require more efficient equipment the equipment in Table 5 was used.

Table 4 Standard Efficiency Equipment

Reference House	Equipment
Gas	80 AFUE gas furnace + 13 SEER air conditioner (CZ 5-7) or 14 SEER (CZ 4)
	40 gallon gas natural draft water heater, 0.58 UEF
Electric	14 SEER/8.2 HSPF air source heat pump
	50 gallon electric water heater, 0.92 UEF

Table 5 High Efficiency Equipment Options

Reference House	Equipment
Gas	95 AFUE gas furnace + 16 SEER air conditioner
	Tankless gas direct vent water heater, 0.82 UEF
Electric	16 SEER/10 HSPF heat pump
	Heat pump water heater, 50 gal, 2.0 EF

Changes for 2021

The 2021 IECC contains changes relative to the 2018 IECC that will result in increased energy savings, and increased construction costs. Appendix A contains a complete list of code changes that were evaluated for this analysis, but the most significant changes include:

- Improved envelope requirements (See Appendix D)
  - Increased ceiling insulation in climate zones 2 through 8
  - Continuous insulation on above-grade walls in climate zones 4 and 5
  - Slab insulation in climate zones 3 through 5
  - Lower window U-factor in climate zones 3 and 4
- Higher efficacy lighting
- Increased fan efficacy, and testing requirements
- Balanced ventilation (ERV/HRV) in climate zones 7 and 8
- One of five 'additional efficiency package options' (See RE209 in Appendix A for details):
  - Enhanced envelope performance option[11]
  - More efficient HVAC equipment performance option
  - Reduced energy use in service water-heating option
  - More efficient duct thermal distribution system
  - Improved air sealing and efficient ventilation option

Some homes meet the requirements of the additional efficiency package options due to construction practices (i.e., ducts located in conditioned space for homes with basements and conditioned crawlspaces), or code requirements (i.e., ERV/HRV required in climate zones 7 and 8). For these homes, no changes are needed to meet this requirement, but for others a change will need to be made and it will result in additional costs and savings.

All code changes that were reflected in the energy models are noted in Table 6.

Results

Construction Costs

The incremental construction costs considered in this analysis are shown in Table 6, with details in Appendix A and B. The weighted average incremental construction cost is shown in Table 7.

Table 6 Incremental Construction Cost of Individual Code Change for the Reference House

Proposal	Description	Affected CZs	Reference House
RE7*	Lighting: revised definition of high-efficacy	All	$0
RE18/20/21	Certificate: additional info	All	$0
RE29*	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742
	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680
RE32*	Slab edge: NR to R10/2 (CZ3)	3	$709
	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709
RE33*	Ceiling insulation R38 to R49	2-3	$226
RE36*	Ceiling insulation R49 to R60	4-7	$198
RE34	Floors, removes exception for min R19 if fills cavity	5-8	$0

[11] The enhanced envelope option was not evaluated for this study.

RE35*	Windows: reduces U-value from 0.32 to 0.30	3-4	$67
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6
RE72	Air seal narrow framing cavities	All	$0
RE82	Air seal rim (basement; unvented crawlspace)	All	$0
	Air seal rim (slab, vented crawlspace)	All	$0
RE96	House tightness, allows trade-off for performance path	All	$0
RE103	Air seal electrical & communication outlet boxes	All	$0
RE106	Thermostat: requires 7-day programming	All	$0
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47
RE130	Adds requirement to test whole-dwelling ventilation	All	$31
RE133*	Updates ventilation fan efficacy (affects bath EF)	All	$0
RE139*	Requires ERV/HRV in CZ 7-8 (includes RE134 reqs.)	7	$1,742
RE145*	Lighting: 100% high-efficacy; controls (slab)	All	$33
	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$41
RE148	Lighting, commercial	All	$0
RE151	Performance path backstop: 2009 IECC	All	$0
RE178	Performance path ventilation type to match proposed	All	$0
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	$0
RE209*	Additional efficiency package options:	All	
	HVAC, gas house, 95 AFUE/16 SEER for 13 SEER baseline	5-7	$1,142
	HVAC, gas house, 95 AFUE/16 SEER for 14 SEER baseline	4	$952
	HVAC, electric house, 10 HSPF/18 SEER heat pump	All	$2,566
	Water Heater, gas house, tankless direct-vent, 0.82 UEF	All	$549
	Heat Pump Water Heater, electric house, 50 gal, 2.0 EF	2-3	$1,178
	Ventilation, gas house	4-7	$1,707
	Ventilation, electric house	3-5	$1,707
	Ventilation, electric house with improved air tightness	2	$2,057
	Duct, slab house, buried ducts in attic	2-3	$2,374
	Duct, slab house, buried ducts in attic	4-7	$658
	Duct, vented crawlspace house	3	($809)
	Duct, vented crawlspace house	4	($36)

***Indicates a code change that was included in the energy modeling analysis for this study (10 total)**

Table 7 Incremental Construction Cost for 2021 Reference House, weighted averages

Total Incremental Cost	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
Without additional efficiency package options	$1,373	$297	$902	$2,254	$3,102	$321	$2,050
With HVAC option	$3,273	$2,864	$3,469	$3,206	$4,245	$1,464	$3,192
With Water Heater option	$2,274	$1,475	$2,080	$2,803	$3,651	$870	$2,599
With Ventilation option	$3,161	$2,354	$2,609	$3,961	$4,809	$2,028	$2,050
With Duct option, slab house	$3,243	$2,672	$3,447	$3,444	$4,315	$926	$2,669
With Duct option, vented crawlspace house	n/a	n/a	-$437	$2,049	n/a	n/a	n/a

Table 8 contains code changes that were not included in this analysis either because they are unlikely to impact many homes or would result in some energy savings but their impacts were not modeled.

Table 8 Potential Additional Cost of Individual Code Change for the Reference House

Proposal	Description	Affected CZ	Reference House
RE47	Attic pull-down stair: adds exception to insulation requirements	2-3	($87)
	Same	4	($113)
RE49	Baffles at tray ceiling (example)	2-3	$125
	Same	4-7	$157
RE52	Walls: removes exception for reduced c.i. at WSP	3-7	$1,283 to $2,692
RE55	Adds requirements for unconditioned basements	4-5	$97
RE109	Floor insulation for ducts in conditioned space: min R19	2	$34
RE134	Adds min efficacy for air handlers if integrated w/ventilation	All	$1,115
RE149	Lighting: exterior controls	All	$22

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Energy Use Costs and Savings

Modeled energy costs are shown in Table 9, and savings in Table 10, both as weighted averages. Complete energy use data for all homes modeled is in Appendix E.

Table 9 Annual Energy Use Cost for Reference House, weighted averages

	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 baseline, all houses	$2,129	$2,224	$2,028	$1,934	$2,279	$2,367	$2,599
slab houses only	$2,074	$2,224	$2,025	$1,807	$2,156	$2,222	$2,735
vented houses only			$1,960	$1,827			
2021 without additional efficiency package options	$2,015	$2,163	$1,890	$1,798	$2,137	$2,289	$2,514
2021 with HVAC option	$1,881	$2,045	$1,769	$1,680	$1,959	$2,093	$2,266
2021 with Water Heater option	$1,922	$2,029	$1,742	$1,761	$2,106	$2,261	$2,505
2021 with Ventilation option	$1,993	$2,144	$1,876	$1,778	$2,104	$2,231	$2,495
2021 with Duct option, slab house	$1,852	$2,047	$1,790	$1,586	$1,890	$1,985	$2,419
2021 with Duct option, vented crawlspace house			$1,845	$1,644			

Table 10 Energy Cost Savings relative to 2018 Baseline Reference House

	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options	5.3%	2.8%	6.8%	7.1%	6.2%	3.3%	3.3%
2021 with HVAC option	11.6%	8.0%	12.8%	13.1%	14.1%	11.5%	12.8%
2021 with Water Heater option	9.7%	8.7%	14.1%	8.9%	7.6%	4.5%	3.6%
2021 with Ventilation option	6.4%	3.6%	7.5%	8.1%	7.7%	5.7%	n/a
2021 with Duct option, slab house	10.7%	8.0%	11.6%	12.3%	12.3%	10.6%	11.6%
2021 with Duct option, vented crawlspace house			5.8%	10.0%			

Cost Effectiveness

Cost effectiveness is calculated based on the data in Table 7 and Table 9 using the metrics described previously.

Table 11a summarizes the simple payback relative to the 2018 IECC, these results are informative, but Table 11b summarizes the weighted LCC cost for the various configurations of 2021 IECC compared to the 2018 IECC, which is more indicative of the cost-effectiveness of the 2021 IECC.

Table 11a Simple Payback relative to 2018 Baseline Reference House, years

	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options	11	5	6	16	22	4	25
2021 with HVAC option	14	16	13	13	13	5	10
2021 with Water Heater option	12	8	7	16	21	8	28
2021 with Ventilation option	24	29	18	26	28	15	20
2021 with Duct option, slab house	15	15	15	16	16	4	8
2021 with Duct option, vented crawlspace house			0	11			

In Table 11b, and for other LCC results, a negative LCC indicates a net savings, and a cost-effective code change. The packages which have a negative LCC have cells with blue text and show that in each location analyzed there are multiple cost-effective options with the structure of the 2021 IECC. Additionally, the cost-effectiveness of the 2021 IECC in practice is likely to be better for two reasons. First, as described in Appendix A, cost estimates are conservative because publicly available sources were used, and a builder is likely to purchase many products at a lower price due to their bulk purchasing power. And second, this analysis uses the Prescriptive Compliance Option (R401 through R404), and builders may be able to find more cost-effective ways to achieve the same level of performance and comply using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406) which have more flexibility in the measures a builder can use in their homes. The results show that construction based on the 2021 IECC is cost effective when compared to the 2018 IECC across all climate zones.

Table 11b LCC* relative to 2018 Baseline Reference House ($ / house)

	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options	(1,625.67)	(1,350.06)	(2,783.91)	(1,318.71)	(690.87)	(1,757.92)	1,411.09
2021 with HVAC option	(1,932.88)	(180.50)	(1,710.75)	(2,728.63)	(3,300.21)	(4,796.20)	(2,947.04)
2021 with Water Heater option	(2,590.72)	(2,963.03)	(4,790.45)	(1,295.80)	(550.40)	(1,507.53)	2,131.96
2021 with Ventilation option	1,102.13	1,892.34	(49.29)	1,388.91	1,679.62	(9.37)	933.64
2021 with Duct option, slab house	(2,670.47)	(2,199.57)	(2,958.79)	(2,324.45)	(2,612.12)	(5,121.73)	(3,784.46)
2021 with Duct option, vented crawlspace house	n/a	n/a	(3,688.02)	(2,759.88)	n/a	n/a	n/a

*Negative LCC indicates net savings

The HIRL report included an example of a comparison of savings for a gas and electric home in climate zone 3 in “Table 12. Example Comparison of Gas vs. Electric Energy Cost Savings relative to 2018 baseline.” However, the report did not publish the energy use data for individual gas homes in climate zone 3, so that comparison and the relative cost-effectiveness could not be evaluated in this analysis.

Cost Effectiveness of Selected Code Changes

Individual code changes were evaluated to show their costs, savings, and cost-effectiveness against the 2018 IECC baseline. For thermal envelope changes, Table 13 shows the incremental costs, Table 14 shows the associated modeled energy cost, and Table 15 shows the energy savings.

Table 13 Incremental Construction Cost of Thermal Envelope Changes

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
Ceiling insulation	$233	$233	$204	$204	$204	$204
Slab insulation	n/a	$709	$709	$709	n/a	n/a
Wall continuous insulation	n/a	n/a	$1,742	$2,680	n/a	n/a
Window U-factor	n/a	$67	$67	n/a	n/a	n/a

Table 14 Annual Energy Use Cost of Thermal Envelope Changes

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 baseline, all houses	$2,224	$2,028	$1,934	$2,279	$2,367	$2,599
2018 baseline, slab houses only		$2,025	$1,807	$2,156		
2018 + 2021 ceiling insulation	$2,216	$2,017	$1,925	$2,269	$2,353	$2,584
2018 + 2021 slab insulation, slab houses only	n/a	$1,936	$1,773	$2,120	n/a	n/a
2018 + 2021 wall continuous insulation	n/a	n/a	$1,886	$2,217	n/a	n/a
2018 + 2021 window U-factor	n/a	$2,021	$1,924	n/a	n/a	n/a

Table 15 Energy Cost Savings of Thermal Envelope Changes relative to 2018 Baseline Reference House

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 + 2021 ceiling insulation	0.3%	0.6%	0.5%	0.5%	0.6%	0.6%
2018 + 2021 slab insulation, slab houses only	n/a	4.5%	1.9%	1.6%	n/a	n/a
2018 + 2021 wall continuous insulation	n/a	n/a	2.5%	2.7%	n/a	n/a
2018 + 2021 window U-factor	n/a	0.4%	0.5%	n/a	n/a	n/a

Using the data above, the cost-effectiveness of the thermal envelope changes was evaluated with results in Table 16. Additionally, Table 17 contains data on the cost effectiveness of an HRV in climate zone 7. The data shows that some measures are cost-effective and some are not for the homes modeled. There are several key takeaways from these results.

- Individual code changes to the 2018 IECC may not be cost-effective by themselves, but the overall result for the 2021 IECC is that it is cost-effective (as shown in Table). These results will vary for each individual home with unique cost and savings resulting from different assembly areas.
- As mentioned before, costs may be less if a home complies using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406). With the information below a builder may choose to invest in more in measures that are cost-effective and less in those that are not without impacting the overall performance of the home.

Table 16 Simple Payback relative to 2018 Baseline Reference House for Thermal Envelope Changes, years

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 + 2021 ceiling insulation	31	20	22	19	15	14
2018 + 2021 slab insulation, slab houses only	n/a	8	20	20	n/a	n/a
2018 + 2021 wall continuous insulation	n/a	n/a	36	43	n/a	n/a
2018 + 2021 window U-factor	n/a	9	6	n/a	n/a	n/a

Table 17 Cost effectiveness of HRV in CZ 7

	CZ 7 Duluth
Incremental cost of HRV	$1,742
Annual energy cost, 2021* without HRV	$2,539
Annual energy cost, 2021* with HRV	$2,514
Energy cost savings for HRV	1.0%
Simple payback years	12
*Without additional efficiency package options	

The 2021 IECC requires one of five 'additional efficiency package options' (See RE209 in Appendix A for details). The cost-effectiveness of these were evaluated based on data in Table 18 and Table 19, with results in Table 20, and Table 21.

Table 18 Incremental Construction Cost of Additional Efficiency Package Options

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	$1,900	$2,567	$2,567	$952	$1,143	$1,143
Water Heater option	$901	$1,178	$1,178	$549	$549	$549
Ventilation option	$1,788	$2,057	$1,707	$1,707	$1,707	$1,707
Duct option, slab house	$1,870	$2,374	$2,545	$1,190	$1,213	$605
Duct option, vented crawlspace house			($1,339)	($205)		

Table 19 Annual Energy Use Cost of Additional Efficiency Package Options

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options, all houses	$2,163	$1,890	$1,798	$2,137	$2,289	$2,514
slab houses only	$2,163	$1,867	$1,656	$1,999	$2,166	$2,639
vented houses only	n/a	$1,890	$1,711	n/a	n/a	n/a
2021 with HVAC option	$2,045	$1,769	$1,680	$1,959	$2,093	$2,266
2021 with Water Heater option	$2,029	$1,742	$1,761	$2,106	$2,261	$2,505
2021 with Ventilation option	$2,144	$1,876	$1,778	$2,104	$2,231	$2,495
2021 with Duct option, slab house	$2,047	$1,790	$1,586	$1,890	$1,985	$2,419
2021 with Duct option, vented crawlspace	n/a	$1,845	$1,644	n/a	n/a	n/a

Table 20 shows the savings of the additional efficiency package options relative to the base 2021 code. The packages were designed to achieve roughly 5% additional savings, and in this analysis the savings ranged from 0.4% to 9.9%, with an average of 4.4%.

Table 20 Energy Cost Savings of Additional Efficiency Package Options relative to 2021 without packages

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	5.4%	6.4%	6.5%	8.3%	8.5%	9.9%
Water Heater option	6.2%	7.8%	2.0%	1.5%	1.2%	0.4%
Ventilation option	0.9%	0.7%	1.1%	1.6%	2.5%	0.8%
Duct option, slab house	5.4%	4.1%	4.3%	5.5%	8.4%	8.4%
Duct option, vented crawlspace house	n/a	2.4%	3.9%	n/a	n/a	n/a

Table 21 shows the cost-effectiveness of each additional efficiency package option relative to the base 2021 IECC. This data by itself does not provide meaningful conclusion because it uses the 2021 IECC as a baseline, and the efficiency package options along with all the other code changes collectively achieve savings beyond the 2018 IECC. However, it can be used to infer the relative cost-effectiveness of each of these options. Table 11 can be used to make the same comparison, and as mentioned previously builders may be able to find more cost-effective ways to achieve the same level of performance and comply using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406).

Table 21 Simple payback of efficiency package options relative to 2021 house without packages, years

	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	21.8	21.3	8.1	6.4	5.8	4.6
Water Heater option	8.8	8.0	15.3	17.9	21.2	75.3
Ventilation option	109.7	134.9	109.8	60.5	30.3	0.0
Duct option, slab house	20.5	30.7	9.3	6.0	3.6	3.0
Duct option, vented crawlspace house	n/a	0.0	0.0	n/a	n/a	n/a

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Conclusions

The HIRL report was analyzed and updated with new costs for code changes based on publicly available sources, and cost-effectiveness was re-examined using metrics from the DOE Methodology that is used to evaluate the cost-effectiveness of code changes (i.e., Life-Cycle Cost). Key findings from this analysis are:

- The 2021 IECC is cost effective when compared to the 2018 IECC across all climate zones, and there are multiple cost-effective compliance options in each climate zone.
- The cost-effectiveness of the 2021 IECC in practice is likely to be better for two reasons. First, as described in Appendix A, cost estimates are conservative because publicly available sources were used, and a builder is likely to purchase many products at a lower price due to their bulk purchasing power. And second, this analysis uses the Prescriptive Compliance Option (R401 through R404), and builders may be able to find more cost-effective ways to achieve the same level of performance and comply using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406).
- There are significant savings relative to the 2018 IECC, ranging from a national average of 6.4% to 11.6%, depending on which additional efficiency package option is assumed.
- The weighted national average incremental cost of the code changes ranges from $2,695 to $3,694 depending on which additional efficiency package option is assumed.
- Individual code changes to the 2018 IECC have varying ranges of simple payback, but overall, the 2021 IECC is cost-effective as a package of measures that work together to achieve significant cost-effective savings (as shown in Table 11b). These results will vary for each individual home with unique cost and savings resulting from different assembly areas.
- As mentioned before, costs may be less if a home complies using the Total Building Performance Option (R405), or the Energy Rating Index Option (R406). With the information below a builder may choose to invest in more in measures that are cost-effective and less in those that are not without impacting the overall performance of the home.

APPENDIX A: COST OF INDIVIDUAL CODE CHANGES

Code changes are summarized below along with their estimated incremental costs. This analysis evaluated and updated the incremental costs of the code changes reported in the HIRL report. Material costs were generally updated to use publicly available sources from retailers and distributors in November 2021, with sources shown in footnotes. When the same product was available from multiple retailers, the least cost option was used as a source because a builder has higher purchasing power and like likely to purchase many products at a lower price due to their bulk purchasing power. Even with this approach the material costs used in this report are likely to be higher than what a builder would pay, therefore producing conservative results. Unless noted, the majority of labor costs from the HIRL report were used and were sourced from hour estimates and labor rates from RS Means.[12] Some code changes that the HIRL report contained a cost were determined to result in no incremental cost after a review of the code change, and those are noted as well.

The total cost to the builder has a 17.5% markup applied to reflect the builder's gross profit margin and therefore the cost to the consumer. Many aspects of homebuilding are subcontracted out, so individual costs for labor, materials have markups applied by the subcontractor with a markup of 10% on material and equipment and 17.5% on labor, the columns marked "w/O&P" include these markups. To reflect that the majority, but not all, aspects of homebuilding are subcontracted out a factor of 79.3% is applied to these subcontractor markups to reflect the average share of construction costs that are subcontracted dating back to 2012.[13] The 10% markup is based on RS Means assumptions,[14] and the 17.5% markup is based on an average gross profit margin for homebuilders over multiple years, with a low of 14.4% in 2008, a high of 20.8% in 2006, and with 18.3% as the most recent value from 2020.[15, 16]

RE7

Reference Code Section

R202 Defined terms; R404.1 Lighting equipment

Summary of Code Change:

This code change revises the definition of high-efficacy lighting to reflect current lighting market conditions more accurately. Previously the definition used the following for efficacy requirements:

1. 60 lumens per watt for lamps over 40 watts.
2. 50 lumens per watt for lamps over 15 watts to 40 watts.
3. 40 lumens per watt for lamps 15 watts or less.

Now the definition uses 65 lumens per watt, or 45 lumens per watt for luminaires.

Cost Implication of the Code Change

This code change does not impact the cost of construction because CFL and LED lighting that was being used to meet the definition of 'High-Efficacy' already exceeded the new requirements. Therefore, no cost impact is assumed for the reference home.

12 https://www.rsmeans.com/
13 Source: https://www.nahb.org/-/media/NAHB/news-and-economics/docs/housing-economics-plus/special-studies/2020/special-study-average-new-home-uses-24-different-subcontractors.pdf
14 Source: https://www.rsmeans.com/resources/articles/what-is-construction-estimating
15 Source: https://eyeonhousing.org/2019/03/builders-profit-margins-continue-to-slowly-increase/
16 Source: https://www.coconstruct.com/blog/despite-turbulent-2020-home-builder-profit-margins-grew-8-5-yoy

RE18, RE20, RE21

Reference Code Section

R401.3 Certificate

Summary of Code Change:

This code change requires additional information on the certificate for the home. RE18 requires information for onsite renewable systems (e.g., capacity). RE20 requires additional information on the certificate about the builder, code edition, and compliance path. RE21 requires additional information about insulation and ERI scores.

Cost Implication of the Code Change

The code change proposal will not increase or decrease the cost of construction. The administrative change of reporting additional, readily-available, information on a certificate that is already produced takes no additional time for a builder or rater. Therefore, no cost impact is assumed for the reference home.

RE29

Reference Code Section

Table R402.1.2; Table R402.1.3

Summary of Code Change:

This code change increases insulation required in above-grade walls in climate zones 4 and 5 to match existing requirements in climate zone 6.

Cost Implication of the Code Change

This code change will increase the cost of construction for all homes in climate zones 4 and 5. For 2x4 walls the cost is based on an increase from R-13+5 to R-13+10, and for 2x6 walls the cost is based on an increase from R-20 to R-20+5. A weighted average of these two costs is used in the analysis based on data collected by the U.S. DOE's Residential Energy Code Field Studies for homes built in climate zones 4 and 5.

Cost to add information to the certificate, Climate zone 4

Component	Unit	Cost, from below	Weight[17]	Cost, weighted
2x4 wall, increase c.i. from R5 to R10	$/house	$1,112.07	73%	$810.20
2x6 wall, increase c.i. from R0 to R5	$/house	$3,433.00	27%	$931.90
Total to Consumer				$1,742.10

Cost to add information to the certificate, Climate zone 5

Component	Unit	Cost, from below	Weight[17]	Cost, weighted
2x4 wall, increase c.i. from R5 to R10	$/house	$1,112.07	32%	$360.58
2x6 wall, increase c.i. from R0 to R5	$/house	$3,433.00	68%	$2,319.88
Total to Consumer				$2,680.46

Cost to increase c.i. from R5 to R10 for 2x4 wall

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	(2,300)	($2,921.81)
XPS, 15 psi, 2", R10[19]	SF	$1.04	$0.49	$1.53	$1.68	2,300	$3,868.29
Total to Builder							$946.48
Total to Consumer							$1,112.07

Cost to increase c.i. from none to R5 for 2x6 wall

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	2,300	$2,921.81
Total to Builder							$2,921.81
Total to Consumer							$3,433.00

17 Source: https://www.energycodes.gov/residential-energy-code-field-studies

18 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-5-polystyrene-foam-board-insulation-1-x-4-x-8/565243/p-1444450471646-c-5779.htm?tid=4167155398492965668&ipos=2

19 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-10-polystyrene-foam-board-insulation-2-x-4-x-8/654957/p-1444450471143-c-5779.htm?tid=-9057347254943865747&ipos=6

RE32

Reference Code Section

Table R402.1.3

Summary of Code Change:

This code change increases slab insulation in climate zones 3, 4 and 5 specified by Table R402.1.3. Climate zone 2 is increased from no insulation to R-10, for a depth of 2 ft. Climate zones 4 and 5 are increased from R-10 for a depth of 2 ft, to R-10 for a depth of 4 ft.

Cost Implication of the Code Change

This code change will increase the cost of construction by requiring more slab insulation to be installed in climate zones 3, 4, and 5. All climate zones will require an additional 400 sq. ft. of R-10 extruded polystyrene (XPS) slab insulation because the slab perimeter is 200 sq. ft. and the additional slab edge depth is an additional 2 ft.

Cost of additional slab edge insulation, CZ 3

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 25 psi, 2" thick, R-10[20]	SF	$0.98	$0.40	$1.38	$1.51	400	$603.28
Total to Builder							$603.28
Total to Consumer							$708.83

Cost of additional slab edge insulation, CZ 4-5

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 25 psi, 2" thick, R-10[20]	$603.28	$0.98	$0.40	$1.38	$1.51	400	$654.65
Total to Builder							$603.28
Total to Consumer							$708.83

20 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-10-polystyrene-foam-board-insulation-2-x-4-x-8/271000/p-1444450496132.htm

RE33, RE36

Reference Code Section

Table R402.1.2, Table R402.1.3, R402.2.1

Summary of Code Change:

This code change increases the ceiling insulation in climate zones 2 through 8 by a net of R-11. Climate zones 2 and 3 are increased to R-49 from R-38 by RE33, and climate zones 4 through 8 are increased to R-60 from R-49 by RE36.

Cost Implication of the Code Change

This code change will increase the cost of construction in climate zones 2 through 8. The cost is based on the incremental cost of blown cellulose in a vented attic and is assumed to be the same for both code changes, including the same labor and equipment costs. A portion of the attic will not be impacted by this code change because the full-height of the insulation cannot be achieved (i.e., at the eave). So, when the nominal R-value required increase from R-38 to R-49, only the area of the attic where the full R-38 was achieved previously will have improved performance, and an associated cost. Therefore, the areas below were adjusted to reflect this.

Cost to Increase ceiling insulation from R-38 to R-49

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
R-38 attic insulation, blown cellulose[21]	SF	$0.37	$0.61	$0.36	$1.34	$1.49	(1414)	($2,103.26)
R-49 attic insulation, blown cellulose	SF	$0.50	$0.61	$0.36	$1.47	$1.62	1414	$2,295.94
Total to Builder								$192.68
Total to Consumer								$226.39

Cost to Increase ceiling insulation from R-49 to R-60

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
R-49 attic insulation, blown cellulose[21]	SF	$0.37	$0.61	$0.36	$1.34	$1.49	(1235)	($1,837.33)
R-60 attic insulation, blown cellulose	SF	$0.50	$0.61	$0.36	$1.47	$1.62	1235	$2,005.65
Total to Builder								$168.32
Total to Consumer								$197.76

21 Source: https://www.menards.com/main/building-materials/insulation/loose-fill-insulation/insulmax-reg-blow-in-cellulose-insulation/1611640/p-1520836262471-c-5777.htm?tid=4389096187601806274&ipos=1

RE34

Reference Code Section

Table R402.1.3

Summary of Code Change:

This code change removed the exception for floor insulation R-value which allowed insulation sufficient to fill the cavity if it provided at least R-19. This exception only applied to climate zones 5 to 8.

Cost Implication of the Code Change

This code change can increase the cost of construction, by requiring more insulation, if the exception was being used. However, the reference house does not have floor insulation above unconditioned space. Therefore, no cost impact is assumed for the reference home.

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RE35

Reference Code Section

Table 402.1.2 and Table R402.1.3

Summary of Code Change:

This code change reduces the maximum U-factor for windows in CZ3 and 4 from 0.32 to 0.30. The change also adds a footnote that a maximum window U-factor of 0.32 shall apply in CZ 5 to 8 for buildings located at high elevations, or in regions with high wind.

Cost Implication of the Code Change

This code change will increase the cost of construction in CZ 3-4. EPA's ENERGY STAR program found that window prices vary widely, and thermal performance was not the primary driver of consumer prices, which makes it hard to develop a clear incremental cost for changes in window thermal performance. Several sources were consulted showing a wide range of estimated incremental costs for this code change. Four different window incremental cost model / methods were collected in this analysis to better understand it.

Various Sources for Cost to reduce the window U-factor from 0.32 to 0.30

Component	Unit	Material
California Energy Commission[22]	SF	$0.15
ENERGY STAR Windows v7.0[23]	SF	$0.40
Department of Energy[24]	SF	$0.14
Energy Trust of Oregon[25]	SF	$0.58

The v6.0 ENERGY STAR window requirements, established in 2015, require a U-factor of 0.30 for the Noth-Central and South-Central climates, which generally align with climate zones 3 and 4.[26] Additionally, ENERGY STAR estimates the 2020 market penetration of windows at 84%.[27] Therefore for many builders there will be no incremental cost for the code change, but because that is not the case for all builders the lowest cost from the above sources will be used for this analysis.

Cost to reduce the window U-factor from 0.32 to 0.30

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Incremental Cost of Window	SF	$0.14	$0.00	$0.14	$0.15	375	$56.67
Total to Builder							$56.67
Total to Consumer							$66.58

22 Source: https://efiling.energy.ca.gov/GetDocument.aspx?tn=222199&DocumentContentId=27369
23 Source: https://www.energystar.gov/sites/default/files/asset/document/ES_Residential_WDS_Draft%201_Criteria%20Analysis%20Report.pdf
24 Source: https://www.energycodes.gov/sites/default/files/2021-07/2021IECC_CostEffectiveness_Final_Residential.pdf
25 https://www.energytrust.org/wp-content/uploads/2019/02/Energy-Trust-of-Oregon-Windows-2018-Market-Research-final.pdf
26 Source: https://www.energystar.gov/sites/default/files/Windows_Doors_and_Skylights_Program_Requirements%20v6.pdf
27 Source: https://www.energystar.gov/sites/default/files/asset/document/2020%20USD%20Summary%20Report_Lighting%20%20EVSE%20Update.pdf

RE37

Reference Code Section

Table 402.1.2 and Table R402.1.3

Summary of Code Change:

This code change revised the climate zone 5 glazed fenestration SHGC to 0.40, where there previously was no requirement.

Cost Implication of the Code Change

This code change is unlikely to increase the cost of construction. Data provided by the ENERGY STAR program shows that many windows meeting the climate zone 5 U-factor requirement of 0.30, meet a SHGC of 0.40.[28] Additionally, if a home was complying with code through the Total Building Performance Option (Section R405), a 0.40 SHGC would have been used for modeling where there was no requirement. Therefore, no cost impact is assumed for the reference home.

28 Source: https://www.energystar.gov/sites/default/files/asset/document/ES_Residential_WDS_Draft%201_Criteria%20Analysis%20Report.pdf

RE46

Reference Code Section

R402.2.4 Access hatches and doors

Summary of Code Change:

This code change does not add any new requirements, instead it separates prescriptive and mandatory provisions into separate sections.

Cost Implication of the Code Change

There is no direct cost implication from this code change because it does not add any new requirements. However, the cost of the additional ceiling insulation required in all climate zones (RE33 and RE36) is reflected here where more insulation would be required on an attic access hatch. The cost is based on securing an additional 3" of EPS foam board to an attic access hatch.

Cost to increase the insulation above an attic access by R-11

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
EPS, 3" thick, R-12[29]	SF	$0.40	$0.40	$0.80	$0.89	6	$5.34
Total to Builder							$5.34
Total to Consumer							$6.28

29 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/expanded-polystyrene-foam-board-insulation-4-x-8/1632105/p-1444435971090.htm

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RE47

Reference Code Section

R402.2.4 Access hatches and doors

Summary of Code Change:

This code change adds an exception attic pull-down stairs in CZ 0-4, which are not required to comply with the insulation level of the surrounding surfaces if the hatch meets:

- Average U-factor of 0.10 or R-value of R-13 or greater,
- 75% of panel area is insulated to R-13 or greater,
- Net area of the opening is less than 13.5 square feet, and
- The permitter is weather-stripped.

Cost Implication of the Code Change

This code change may decrease the cost of construction but is likely to have no impact on costs in most cases. No cost impact is assumed for the reference home, however, these costs are shown below for illustrative purposes.

Cost savings to reduce insulation above attic pull-down stair for CZ 2-3 (R49 ceiling)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5 (one 1" layer) [18]	SF	$0.70	$0.45	$1.15	$1.27	13.5	$17.15
XPS, 15 psi, 2", R10 (one 2" layer)[19]	SF	$1.04	$0.49	$1.53	$1.68	13.5	$22.71
XPS, 15 psi, 2", R10 (five 2" layers)[19]	SF	$1.04	$0.49	$1.53	$1.68	(67.5)	($113.53)
Total to Builder							($73.67)
Total to Consumer							($86.56)

Cost savings to reduce insulation above attic pull-down stair for CZ 4 (R60 ceiling)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5 (one 1" layer)[18]	SF	$0.70	$0.45	$1.15	$1.27	13.5	$17.15
XPS, 15 psi, 2", R10 (one 2" layer)[19]	SF	$1.04	$0.49	$1.53	$1.68	13.5	$22.71
XPS, 15 psi, 2", R10 (six 2" layers)[19]	SF	$1.04	$0.49	$1.53	$1.68	(81)	($136.23)
Total to Builder							($96.38)
Total to Consumer							($113.24)

RE49

Reference Code Section

R402.2.4 Access hatches and doors

Summary of Code Change:

This code change adds a requirement to prevent loose-fill insulation in the attic from spilling from higher to lower sections with a baffle or retainer.

Cost Implication of the Code Change

This code change may increase the cost of construction where there is variation in the ceiling / attic height, but is likely to have no impact in most cases. Generally, this code change will not increase the cost of construction. illustrate this potential cost, the incremental cost of the insulation and the baffle is shown below. No cost is assumed for the reference home; however, these costs are shown below for illustrative purposes.

Cost to increase the height of insulation baffles at attic access hatch

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Plywood, 3/4" CDX[30]	SF	$1.25	$0.60	$1.85	$2.03	4	$8.13
Total to Builder							$8.13
Total to Consumer							$9.56

Cost to add baffles at tray ceiling (est. 48 LF) for CZ 2-3

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Plywood, 1/2" CDX[31]	SF	$0.74	$0.52	$1.26	$1.40	76	$106.04
Total to Builder							$106.04
Total to Consumer							$124.59

Cost to add baffles at tray ceiling (est. 48 LF) for CZ 4-8

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Plywood, 1/2" CDX[31]	SF	$0.74	$0.52	$1.26	$1.40	96	$133.95
Total to Builder							$133.95
Total to Consumer							$157.38

30 Source: https://www.menards.com/main/building-materials/panel-products/plywood-sheathing/3-4-x-4-x-8-plywood-sheathing/1231182/p-1444431334153-c-13331.htm?tid=5612448418558004428ipos=1

31 Source: https://www.menards.com/main/building-materials/panel-products/plywood-sheathing/1-2-x-4-x-8-plywood-sheathing-3-ply/1231085/p-1444431324783-c-13331.htm?tid=5612448418558004428ipos=6

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RE52

Reference Code Section

Deleted 2018 IECC R402.2.7 Walls with partial structural sheathing

Summary of Code Change:

This code change deleted a section that allowed continuous insulation (c.i.) to be reduced to result in a consistent sheathing thickness. The exception was limited to 40% of the gross wall area and by no more than R-3.

Cost Implication of the Code Change

This code change may increase the cost of construction where the exception was used, but is likely to have no impact in most cases. Generally, this code change will not increase the cost of construction. To illustrate this potential cost, the incremental cost of additional c.i. is shown below. No cost impact is assumed for the reference home; however, these costs are shown below for illustrative purposes.

Cost to install additional ½-inch thickness of continuous insulation

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1/2", R3[32]	SF	$0.37	$0.43	$0.80	$0.89	(1,070)	($956.68)
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	1,070	$1,359.28
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	(1,065)	($2,038.92)
XPS, 15 psi, 1.5", R7.5[33]	SF	$1.03	$0.49	$1.52	$1.67	1,065	$2,680.45
Siding attachment, 2" roofing nail galv[34]	LB	$1.58		$1.58	$1.71	(17)	($29.02)
Siding attachment, 2.5" roofing nail galv[35]	LB	$3.39		$3.39	$3.66	21	$76.88
Total to Builder							$1,091.99
Total to Consumer							$1,283.04

Cost to install OSB over entire wall and cover with 1- XPS

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1/2", R3[32]	SF	$0.37	$0.43	$0.80	$0.89	(1,070)	($956.68)
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	1,070	$1,359.28
OSB, wall, 1/2"[36]	SF	$0.60	$0.44	$1.04	$1.15	1,065	$1,840.91
Siding attachment, 2" roofing nail galv[34]	LB	$1.58		$1.58	$1.71	(17)	($29.02)
Siding attachment, 2.5" roofing nail galv[35]	LB	$3.39		$3.39	$3.66	21	$76.88
Total to Builder							$2,291.37
Total to Consumer							$2,692.26

32 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-3-polystyrene-foam-board-insulation-1-2-x-4-x-8/452873/p-1444450501960-c-5779.htm?tid=8495412447645832707&ipos=4

33 Source: https://www.menards.com/main/building-materials/insulation/foam-board-insulation/owens-corning-reg-foamular-reg-r-7-5-polystyrene-foam-board-insulation-1-1-2-x-4-x-8/654955/p-1444450473323-c-5779.htm?tid=8495412447645832707&ipos=7

34 Source: https://www.homedepot.com/p/Grip-Rite-11-x-2-in-Electro-Galvanized-Steel-Roofing-Nails-30-lb-Pack-2EGRFGBK/100114825?MERCH=REC-_-searchViewed-_-NA-_-100114825-_-N&

35 Source: https://www.fastenal.com/products/details/0228959

36 Source: https://www.menards.com/main/building-materials/panel-products/osb-sheathing/1-2-x-4-x-8-osb/1242809/p-1444422395209-c-13330.htm?tid=8336731822554623792&ipos=2

RE55

Reference Code Section

R402.2.8 Basement walls

Summary of Code Change:

This code change adds requirement for how to insulate and seal unconditioned basements. It includes insulating at the floor overhead, walls surrounding the stairway, door(s) leading to the basement from conditioned space. It also states that no uninsulated duct, domestic hot water or hydronic heating surfaces may be exposed to the basement, and no HVAC supply or return diffusers may serve the basement.

Cost Implication of the Code Change

This code change may increase the cost of construction for a home with unconditioned basement. To illustrate this potential cost, this analysis develops a cost to increase c.i. in the walls surrounding the stairway. No cost impact is assumed for the reference home; however, these costs are shown below for illustrative purposes.

Cost to increase wall insulation in the stairway

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5[18]	SF	$0.70	$0.45	$1.15	$1.27	(200)	($254.07)
XPS, 15 psi, 2", R10[19]	SF	$1.04	$0.49	$1.53	$1.68	200	$336.37
Drywall screw, 2.5"[37]	LB	$1.59		$1.59	$1.72	(1.3)	($2.23)
Drywall screw, 3.5"[38]	LB	$1.59		$1.59	$1.72	1.6	$2.75
Total to Builder							$82.82
Total to Consumer							$97.31

37 Source: https://www.menards.com/main/hardware/fasteners-connectors/screws/drywall-screws/grip-fast-reg-8-x-2-1-2-phillips-drive-flat-head-coarse-thread-drywall-screw-25-lb-box/229-2557/p-1444441860201.htm

38 https://www.menards.com/main/hardware/fasteners-connectors/screws/drywall-screws/grip-fast-reg-10-x-3-1-2-phillips-drive-flat-head-coarse-thread-drywall-screw-25-lb-box/229-2735/p-1444441853388.htm

RE72

Reference Code Section

Table R402.4.1.1 Air barrier, air sealing and insulation installation

Summary of Code Change:

This code change clarifies that "Narrow cavities, of an inch or less, not able to be insulated, shall be air sealed."

Cost Implication of the Code Change

This code change is unlikely to increase the cost of construction. Narrow cavities are likely to already be air sealed (e.g., with expanding foam) as part of a standard air sealing package to achieve the required air leakage rates in code. Additionally other air sealing criteria in this Table are likely to already cover "Narrow Cavities", for example "The space between framing and skylights, and the jambs of windows and doors, shall be sealed." Therefore, no cost impact is assumed for the reference home.

RE82

Reference Code Section

Table R402.4.1.1 Air barrier, air sealing and insulation installation

Summary of Code Change:

This code change clarifies requirements for rim joists, specifying that the air barrier provided must be air sealed to the sill plate and sub floor.

Cost Implication of the Code Change

This code change will not increase the cost of construction because it clarifies and states explicitly that the rim joist air barrier must be sealed, which was already included in the general requirement of this table that any breaks or joints in the air barriers must be sealed. Therefore, no cost impact is assumed for the reference home.

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RE96

Reference Code Section

R402.4.1.2 Testing

Summary of Code Change:

This code change adds flexibility by making the mandatory air leakage 5.0 ACH50, therefore allowing some tradeoffs where 3.0 ACH50 was required before. Because the overall performance target, and prescriptive requirements are unchanged there is no impact on the overall efficiency.

Cost Implication of the Code Change

This code change will not impact the cost of construction because it only adds flexibility to meet the same level of performance and does not meaningfully impact the efficiency of a home. Therefore, no cost impact is assumed for the reference home.

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RE103

Reference Code Section

R402.4.6 Electrical and communication outlet boxes (air-sealed boxes)

Summary of Code Change:

This code change adds a new section to define “air-sealed boxes” that are already required by Table R402.4.1.1 Air Barrier, Air Sealing and Insulation Installation. Specifically, for “Electrical/phone boxes on exterior walls” the table states “The air barrier shall be installed behind electrical and communication boxes. Alternatively, air-sealed boxes shall be installed” which is unchanged from the 2018 IECC.

The new section R402.4.6 adds that air sealed boxes must be tested and sealed per NEMA OS 4, essentially clarifying the intent of the requirement in Table R402.4.1.1

Cost Implication of the Code Change

This code change may increase the cost of construction if the requirements of Table R402.4.1.1 were misinterpreted or not met, and are now met with the clarification of the new section. Additionally, there are no changes to the assumed air leakage rate, which could be achieved by using air-sealed boxes as a detail. Therefore, no cost impact is assumed for the reference home.

RE105

Reference Code Section

R402.5 Maximum fenestration U-factor and SHGC

Summary of Code Change:

This code change revises the weighted average maximum fenestration SHGC permitted using tradeoffs from Section R405 in climate zones 1 through 3 from 0.50 to 0.40.

Cost Implication of the Code Change

This code change is unlikely to impact the cost of construction because windows in climate zones 1 through 3 typically have much better SHGC than the backstop this code change revises. Therefore, no cost impact is assumed for the reference home.

RE106

Reference Code Section

R403.1.1 Programmable thermostat

Summary of Code Change:

This code change clarifies the required capabilities of a programmable thermostat. Specifically, this code change clarifies that programmable thermostats shall be capable of maintaining different temperature set points for different days of the week, where it only previously required different times of the day.

Cost Implication of the Code Change

This code change is unlikely to increase the cost of construction, even though the code change does require additional capabilities of a programmable thermostat. A review of retailors shows that the lowest-priced programmable thermostat often meets the requirements of this code change, so no cost was assigned to this code change. [39] Therefore, no cost impact is assumed for the reference home.

39 Source: https://hvacdirect.com/braeburn-1-heat-1-cool-universal-programmable-thermostat.html

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RE109

Reference Code Section

R403.3.2 Ducts located in conditioned space

Summary of Code Change:

This code change clarifies requirements for ducts to be considered in conditioned space based on location. For example, it clarifies that for ducts in floor cavities to be considered within conditioned space, they must have R-19 insulation between the duct and the unconditioned space.

Cost Implication of the Code Change

Generally, this code change will not increase the cost of construction. However, in climate zones 1 and 2 there potentially could be an increase in cost because the prescriptive floor insulation in those climate zones is R-13. To illustrate this potential cost the incremental cost of the insulation and moving to an oval duct is shown below. No cost impact is assumed for the reference home; however, these costs are shown below for illustrative purposes.

Cost of increase floor insulation within joist bay from R-13 to R-19

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
R-13 unfaced fiberglass batt[40]	SF	$0.52	$0.42	$0.94	$1.04	(80)	($83.35)
R-19 unfaced fiberglass batt[41]	SF	$0.57	$0.49	$1.06	$1.17	80	$93.54
7" round metal duct[42]	LF	$2.77		$2.77	$2.99	(40)	($119.48)
7" oval metal duct[43]	LF	$3.19		$3.19	$3.45	40	$137.81
Total to Builder							$28.52
Total to Consumer							$33.51

40 Source: https://www.homedepot.com/p/Knauf-Insulation-R13-EcoBatt-Unfaced-Fiberglass-Insulation-Batt-3-1-2-in-x-16-in-x-96-in-15-Bags-691011/313646784
41 Source: https://www.homedepot.com/p/Knauf-Insulation-R-19-EcoBatt-Kraft-Faced-Fiberglass-Insulation-Batt-6-1-4-in-x-15-in-x-94-in-12-Bags-690982/313646748
42 Source: https://www.menards.com/main/heating-cooling/ductwork/ductwork-pipe/heating-cooling-products-30-gauge-round-metal-duct-pipe/10107241/p-1444432222926.htm
43 Source: https://www.menards.com/main/heating-cooling/ductwork/ductwork-pipe/heating-cooling-products-oval-metal-duct-pipe/11107600/p-1444432220354.htm

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RE112

Reference Code Section

R403.3.5 Duct testing, R403.3.6 Duct leakage

Summary of Code Change:

This code change removes an exception, and not requires total duct leakage testing for systems where ducts and air handlers are located entirely within the building thermal envelope. For these systems, a leakage limit of 8.0 cubic feet per minute per 100 square feet of conditioned floor area applies.

Cost Implication of the Code Change

This code change will increase the cost of construction for the subset of homes that have ducts in conditioned space, or for homes with conditioned basements and unvented crawlspaces in this analysis. The cost is estimated based on an estimated 30 minutes to conduct the test by a Rater already on site to conduct other tests, as estimated by the ENERGY STAR Multifamily New Construction Program.[44] It does not include any additional costs for additional sealing or re-testing if the system does not meet the leakage limits.

Estimated cost of the duct leakage test

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Charge by rater	HR				$80.00	0.5	$40.00
Total to Builder							$40.00
Total to Consumer							$47.00

44 Source: https://www.energystar.gov/partner_resources/residential_new/homes_prog_reqs/multifamily_national_page

RE130

Reference Code Section

R403.6.3 Testing (new)

Summary of Code Change:

This code change requires testing of mechanical ventilation systems to verify that they meet the minimum ventilation flow rates. An exemption exists for testing certain kitchen local ventilation systems.

Cost Implication of the Code Change

This code change will increase the cost of construction for all houses. Additional testing will need to be conducted by personnel already on-site conducting other tests (e.g., air leakage and duct leakage tests). The code change proposal was based on requirements of the ENERGY STAR program, which estimates testing will take 5 minutes per system by a rater.[45] The Reference House contains 3 bathrooms (with local mechanical ventilation), one kitchen (which may be exempted from testing if local ventilation is present), and potentially one whole-house mechanical ventilation system (if the existing bathroom ventilation system is not used as part of this system). Therefore, it is estimated that there will be 4 tests taking a total of 20 minutes of a Rater's time at a rate of $80 an hour.

Estimated cost of the mechanical ventilation test

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Charge by rater	HR				$80.00	0.33	$26.67
Total to Builder							$26.67
Total to Consumer							$31.33

45 Source: Cost & Savings Document https://www.energystar.gov/partner_resources/residential_new/homes_prog_reqs/national_page

RE133

Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

Summary of Code Change:

This code change updates the mechanical ventilation system fan efficacy to align with the ENERGY STAR v4.0 requirements established in 2015. For a bath fan rated < 90CFM the efficacy increased from 1.4 to 2.8 CFM/Watt, and for a bath fan rated ≥ 90 CFM the efficacy increased from 2.8 to 3.5 CFM/Watt.

Cost Implication of the Code Change

This code change is unlikely to increase the cost of construction. The reference house uses a bath fan for whole-dwelling mechanical ventilation rated at 90 CFM. A review of fans that meet this airflow rate on Home Depot shows that the least cost fan available is rated at 3.6 CFM/Watt, exceeding the 2021 IECC requirement.[46],[47] Further an analysis by DOE determined that there was no incremental cost because all fans on the market exceed these requirements according to the fans listed in the Home Ventilating Institute's database, and all ventilation fans reviewed at Home Depot showed efficacies well above the fan efficacy requirements in the 2021 IECC. [48] Therefore, no cost impact is assumed for the reference home.

46 Source: https://www.homedepot.com/b/Bath-Bathroom-Exhaust-Fans-Bath-Fans/N-5yc1vZc4kq?NCNI-5&searchRedirect=90%2520cfm%2520bath%2520fan&semanticToken=310r20400g22000100_202111181639429610972139167_us-east1-m01v%20310r20400g22000100%20%3E%20rid%3A%7B998426db4b7693b2887d863123f5ed3b%7D%3Arid%20st%3A%7B90%20cfm%20bath%20fan%7D%3Ast%20ct%3A%7Bbath%20fan%7D%3Act%20pt%3A%7Bbath%20fan%7D%3Apt%20nr%3A%7B90%20cfm%20bath%20fan%7D%3Anr%20nf%3A%7Bn%2Fa%7D%3Anf%20qu%3A%7B90%20cfm%20bath%20fan%7D%3Aqu%20qr%3A%7B90%20cfm%20bath%20fan%7D%3Aqr&sortorder=asc&sortby=price

47 Source: https://cyclonerangehoods.com/bath-fans/c90/

48 Source: https://www.energycodes.gov/sites/default/files/2021-07/2021IECC_CostEffectiveness_Final_Residential.pdf

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RE134

Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

Summary of Code Change:

This code change adds efficacy requirements for whole-dwelling mechanical ventilation systems that utilize the air-handler fan. Specifically, a minimum 1.2 cfm/watt.

Cost Implication of the Code Change

This code change may increase the cost of construction of central fan integrated supply ventilation systems, where there is ductwork bringing in outdoor air to the return. This change will not impact homes with exhaust ventilation. The cost is based on upgrading the furnace to a variable-speed furnace, from a multi-speed furnace to meet the required efficacy. For this type of system, when there is no call for heating or cooling the air handler blower fan my still operate to meet ventilation requirements, this will be accomplished through a controller, the controller could wither activate a separate fan (e.g., an existing bath exhaust fan), or activate the air handler to run to only provide ventilation needs. This code change does not require changes to the ventilation controls, which are already commonly used prior to this code change, but the costs are shown below for illustrative purposes.

Incremental cost of variable-speed furnace

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gas furnace, 80 AFUE, multi-speed[49]	EA	$852.00		$852.00	$919.59	(1)	($919.59)
Gas furnace, 80 AFUE, variable-speed[50]	EA	$1,421.00		$1,421.00	$1533.73	1	$1,533.73
Total to Builder							$614.14
Total to Consumer							$721.59

Cost of both variable-speed furnace and ventilator fan

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Furnace, total to Builder from above							$614.14
Air Cycler Controller[51]	EA	$150.50	$0.00	$150.50	$162.44	1	$162.44
Damper[52]	EA	$90.39	$0.00	$90.39	$97.56	1	$97.56
15-amp circuit, duplex outlet, 20' 14/2 NM[53]	EA	$6.82	$23.50	$30.32	$35.58	1	$35.58
Wire, 14/2, add 20'[54]	LF	$0.45	$1.37	$1.82	$1.97	20	$39.41
Total to Builder							$949.13
Total to Consumer							$1,115.18

49 Source: https://hvacdirect.com/goodman-60-000-btu-80-afue-multi-speed-single-stage-gas-furnace-gmes800603an.html
50 Source: https://hvacdirect.com/goodman-80-afue-60-000-btu-upflow-variable-speed-gas-furnace-gmvc80604bn.html
51 Source: https://www.aircycler.com/collections/shop/products/g2?variant=289397892
52 Source: https://www.homedepot.com/p/Leviton-15-Amp-Residential-Grade-Grounding-Duplex-Outlet-White-10-Pack-M24-05320-WMP/100055784
53 Source: https://www.grainger.com/product/ROMEX-Nonmetallic-Building-Cable-4WZT4
54 Source: https://www.homedepot.com/p/Southwire-1-000-ft-14-2-Solid-Romex-SIMpull-CU-NM-B-W-G-Wire-28827401/202316473

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RE139

Reference Code Section

R403.6.1 Heat or energy recovery ventilation (new)

Summary of Code Change:

This code change adds a new section to require a heat or energy recovery ventilation (HRV or ERV) in climate zones 7 and 8. The equipment mush have a minimum sensible heat recovery efficiency of 65%.

Cost Implication of the Code Change

This code change will increase the cost of construction in climate zones 7 and 8. The cost is estimated based on the incremental cost of installing an ERV instead of an ENERGY STAR bath fan which would have provided whole-house mechanical ventilation, therefore there is some cost savings when downgrading the bath fan. The ERV includes fans which meet the required fan efficacy of 1.2 CFM/Watt, and also includes integrated controls to ensure minimum ventilation needs are met. It is assumed that he ERV will be integrated into the existing HVAC distribution, so limited new ductwork is required.

Cost to install an ERV

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)[55]	EA	$89.05		$89.05	$96.11	(1)	($96.11)
Bath exhaust fan controller[56]	EA	$53.00		$53.00	$57.20	(1)	($57.20)
Bath exhaust fan, standard[57]	EA	$15.39		$15.39	$16.61	1	$16.61
ERV, 100 CFM[58]	EA	$968.99		$968.99	$1,045.86	1	$1,045.86
Installation, labor	HR		$39.90	$39.90	$45.44	2	$90.88
Installation, material	EA	$40.00		$40.00	$43.17	1	$43.17
15-amp circuit, duplex outlet, 20' 14/2 NM[59]	EA	$36.37	$23.50	$59.87	$66.02	1	$66.02
Wire, 14/2, add 20'[60]	LF	$0.38	$1.37	$1.75	$1.97	20	$39.41
GFCI 15-amp 1-pole breaker[61]	EA	$36.37		$36.37	$39.26	1	$39.26
Duct, flexible insulated, 6" dia[62]	LF	$1.60	$2.21	$3.81	$4.24	50	$212.18
Wall cap, 6" dia duct[63]	EA	$7.83	$29.00	$36.83	$41.48	2	$82.95
Total to Builder							$1,483.02
Total to Consumer							$1,742.48

55 Source: https://www.homedepot.com/p/Air-King-ENERGY-STAR-Certified-Quiet-90-CFM-Ceiling-Bathroom-Exhaust-Fan-AK90/203258362
56 Source: https://www.hvacquick.com/products/residential/AirFlow-Boosting/Exhaust-Fan-Controls/Fantech-Ventech-ASHRAE-62-2-Controls
57 Source: https://www.homedepot.com/p/Air-King-Advantage-50-CFM-Ceiling-Bathroom-Exhaust-Fan-AS50/203258495
58 Source: https://www.supplyhouse.com/Panasonic-FV-10VEC2-Intelli-Balance-100-Energy-Recovery-Ventilator-Cold-Climate
59 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1
60 Source: https://www.grainger.com/product/ROMEX-Nonmetallic-Building-Cable-4WZT4
61 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1
62 Source: https://www.homedepot.com/p/Master-Flow-6-in-x-25-ft-Insulated-Flexible-Duct-R6-Silver-Jacket-F6IFD6X300/100396935
63 Source: https://www.supplyhouse.com/Lambro-Industries-361W-6-White-Plastic-Louvered-Wall-Vent

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RE145

Reference Code Section

R404.1 Lighting equipment; R404.2 Interior lighting controls (new)

Summary of Code Change:

This code change increases the percent of high efficacy lighting from 90% to 100% for permanently installed lighting fixtured, and also defines high-efficacy light sources as lamps with an efficacy not less than 65 lumens per watt, or luminaires with an efficacy of 45 lumens per watt. Additionally, it adds a requirement to provide lighting controls (e.g., a dimmer) for all permanently installed light fixtures except for bathrooms, hallways, exterior fixtures, fixtures designed for safety or security.

Cost Implication of the Code Change

The increase of high-efficacy lighting is unlikely to increase the cost of construction in most cases. The use of non-high-efficacy lamps (i.e., incandescent) is uncommon, and recent actions by the Department of Energy indicate a new Standard set at 45 lumens per watt is likely to be established per requirements of the Energy Policy and Conservation Act. [64] Additionally, when incandescent bulbs are available, there are often less expensive high-efficacy (CFL) options available. This is shown in the tables below, but to be conservative the net negative cost is not used in the analysis.

The additional cost of adding dimmer switches will increase the cost of construction, and this is estimated by including the cost of one dimmer for each room that is not-exempted from the requirement.

Cost of high-efficacy lamps and dimmer switches (slab)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
CFL lamp (excluded from total)[65]	EA	$1.25		$1.25	$1.35	4	$5.39
Incandescent lamp (excluded from total)[66]	EA	$1.99		$1.99	$2.15	(4)	($8.59)
Dimmer switch, toggle[67]	EA	$8.32		$8.32	$8.98	4	$35.92
Standard toggle switch[68]	EA	$1.77		$1.77	$1.91	(4)	($7.64)
Total to Builder							$28.28
Total to Consumer							$33.23

Cost of high-efficacy lamps and dimmer switches (basement or crawl space)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
CFL lamp (excluded from total)[65]	EA	$1.25		$1.25	$1.35	4	$5.39
Incandescent lamp (excluded from total)[66]	EA	$1.99		$1.99	$2.15	(4)	($8.59)
Dimmer switch, toggle[67]	EA	$8.32		$8.32	$8.98	5	$44.90
Standard toggle switch[68]	EA	$1.77		$1.77	$1.91	(5)	($9.55)
Total to Builder							$35.35
Total to Consumer							$41.53

64 https://www.regulations.gov/document/EERE-2021-BT-STD-0005-0001
65 Source: https://www.lightbulbs.com/product/maxlite-01504
66 Source: https://www.lowes.com/pd/GE-Classic-60-Watt-Dimmable-A15-Light-Fixture-Incandescent-Light-Bulb-2-Pack/1000444103
67 Source: https://www.homedepot.com/p/Leviton-Trimatron-600-Watt-Single-Pole-Universal-Rotary-Dimmer-White-Light-Almond-R00-RNL06-0TW/301370402
68 Source: https://www.menards.com/main/electrical/light-switches-dimmers-outlets/light-switches/legrand-reg-trademaster-reg-15-amp-1-pole-toggle-light-switch/rc151wcc24/p-1444451212422-c-6324.htm?tid=-3681600139528539746&ipos=3

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Quantities

Room	Lamps	Dimmer
Dining room	6	1
Kitchen	6	1
Breakfast	4	1
Family Room	2	1
Halls	2	0
Baths (3)	10	0
Bedrooms	0	0
Exterior	2	0
Basement	4	1
Crawlspace	4	0
Total, basement	36	5
Total, crawlspace	36	4
Total, slab	32	4
Additional lamps required	4	

RE148

Reference Code Section

R404.1.1 Exterior lighting

Summary of Code Change:

This code change requires compliance with Section C405.4 of the IECC for connected exterior lighting for Group R-2, R-3, and R-4 buildings.

Cost Implication of the Code Change

This code change will not impact the cost of construction for homes constructed to the IRC. Therefore, no cost impact is assumed for the reference home.

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RE149

Reference Code Section

R404.3 Exterior lighting controls (new)

Summary of Code Change:

This code change requires controls on exterior lighting that exceeds 30 Watts.

Cost Implication of the Code Change

This code change will increase the cost of construction, and is estimated by installing two screw-in light sensing controls. No cost impact is assumed for the reference home because the energy savings impact was not modeled, however, these costs are shown below for illustrative purposes.

Cost of exterior lighting control with light sensor

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Control, 100-watt rated, screw-in type[69]	EA	$8.51		$8.51	$9.19	2	$18.37
Total to Builder							$18.37
Total to Consumer							$21.58

69 Source: https://www.homedepot.com/p/Westek-Dusk-to-Dawn-Light-Control-SLC5BCB-4/202524822#product-overview

RE151

Reference Code Section

R405.2 Simulated Performance Alternative - Mandatory Requirements

Summary of Code Change:

This code change establishes a thermal envelope backstop for the performance path of the 2009 IECC.

Cost Implication of the Code Change

Due to the significant increase in stringency of the 2021 IECC over the 2009 IECC this code change is unlikely to have an impact on the cost of construction. Therefore, no cost impact is assumed for the reference home.

RE178

Reference Code Section

Table R405.4.2

Summary of Code Change:

When using the performance compliance option, this code change updates the mechanical ventilation system type for the standard reference design to be the same as the proposed design.

Cost Implication of the Code Change

This code change will have no impact on the cost of construction. Therefore, no cost impact is assumed for the reference home.

RE209

Reference Code Section

R401.2.5 Additional energy efficiency (new); R408 Additional efficiency package options (new)

Summary of Code Change:

This code change creates a new requirement for an 'additional efficiency package options.' This is implemented in Section R401.2.5 by selecting one of five options for the prescriptive path, achieving an additional 5% savings in the performance or Energy Rating Index paths. The five options are:

1. Enhanced envelope performance option
    - Requires a 5% improvement in the total building thermal envelope UA, and weighted average SHGC.
2. More efficient HVAC equipment performance option
    - Requires a ≥ 95 AFUE gas furnace, and 16 SEER air conditioner, or ≥ 10 HSPF / 16 SEER air source heat pump, or ≥ 3.5 COP ground source heat pump.
3. Reduced energy use in service water-heating option
    - Requires a ≥ 0.82 EF fossil fuel service water heating system (i.e., a tankless water heater), or ≥ 2.0 EF electric service water heating system (i.e., a heat pump water heater), or ≥ 0.4 solar fraction solar water heating system.
4. More efficient duct thermal distribution system
    - Requires 100% of ducts and air handlers located entirely within the building thermal envelope, 100% ductless or hydronic systems, or 100% of ducts within conditioned space.
5. Improved air sealing and efficient ventilation option
    - Requires air leakage ≤ 3.0 ACH50, and an energy recovery ventilator (ERV) or heat recovery ventilation (HRV) with at least 75% sensible recovery efficiency.

Cost Implication of the Code Change

This code change will increase the cost of construction. Costs for each option, except the enhanced envelope option, were evaluated.

For the HVAC option, the gas home was upgraded from an 80 AFUE to a 95 AFUE furnace and to a 16 SEER air conditioner, with 13 SEER as a baseline for climate zones 5 to 7 and 14 SEER for climate zones 1 to 4 based on federal appliance standards. The electric home costs reflect an upgrade from an 8.2 HSPF / 14 SEER heat pump to a 10.0 HSPF / 18 SEER unit, which exceeds the 16 SEER requirement, but the cost data used did not have a 16 SEER unit that also met the 10.0 HSPF requirement.

HVAC equipment option for Gas House with baseline 13 SEER AC (CZ 5-7 for this study)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gas furnace, 80 kBtuh, AFUE 80%[70]	EA	$897.00		$897.00	$968.16	(1)	($968.16)
Gas Chimney Vent, 4" dia.[71]	LF	$7.57	$8.45	$16.02	$17.80	(25)	($444.94)
Gas Chimney Vent, 3" dia. (water heater)[72]	LF	$6.29	$8.00	$14.29	$15.90	25	$397.38

70 Source: https://hvacdirect.com/goodman-80-000-btu-80-afue-multi-speed-single-stage-gas-furnace-gmes800803bn.html
71 Source: https://www.grainger.com/product/AMERI-VENT-Gas-Vent-Pipe-3F385
72 Source: https://www.grainger.com/product/AMERI-VENT-Gas-Vent-Pipe-3F381

Gas furnace, 80 kBtuh, AFUE 95%[73]	EA	$1,308.10		$1,308.10	$1,411.88	1	$1,411.88
Vent piping, PVC, 2" dia.[74]	LF	$1.65	$3.02	$4.67	$5.22	40	$208.63
2" concentric vent kit[75]	EA	$37.69		$37.69	$40.68	1	$40.68
Condenser, 3 ton, 13 SEER[76]	EA	$1,254.00		$1,254.00	$1,353.48	(1)	($1,353.48)
Condenser, 3 ton, 16 SEER[77]	EA	$1,557.00		$1,557.00	$1,680.52	1	$1,680.52
Total to Builder							$972.50
Total to Consumer							$1,142.64

HVAC equipment option for Gas House with baseline 14 SEER AC (CZ 2-4 for this study)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Total to Builder, from above							$972.50
Condenser, 3-ton, 14 SEER[78]	EA	$1404.00		$1,404.00	$1,515.38	(1)	($1,515.38)
Condenser, 3-ton, 13 SEER[79]	EA	$1254.00		$1,254.00	$1,353.48	1	$1,353.48
Total to Builder							$810.60
Total to Consumer							$952.41

HVAC equipment option for Electric House: 3 Ton 10 HSPF 18 SEER Heat Pump

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Heat Pump, 8.2 HSPF/14 SEER[80]	EA	$2,769.00		$2,769.00	$2,988.67	(1)	($2,988.67)
Heat Pump, 10.0 HSPF/18 SEER[81]	EA	$4,793.00		$4,793.00	$5,173.24	1	$5,173.24
Total to Builder							$2,184.57
Total to Consumer							$2,566.77

For the water heater option, the gas home cost is estimated with an upgrade from a 40-gallon gas water heater to a tankless water heater that meets this option's performance requirement of a 0.82 EF. The electric home Is estimated with an upgrade from a 50-gallon electric water heater to a heat pump water heater. In this case the requirement is an EF of 2.0, but most heat pump water heaters significantly exceed this level of performance, so a UEF of 3.75 for the water heater is used to estimate costs. The cost of a thermostatic mixing valve was also Included which allows the heat pump water heater tank temperature to safely be set higher, essentially Increasing its capacity.

Water Heater option for Gas House: Direct Vent Water Heater

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
40 gal gas water heater, 0.58 UEF[82]	EA	$469.00	$165.00	$634.00	$694.11	(1)	($694.11)

73 Source: https://www.lowes.com/pd/MRCOOL-88000-Max-BTU-Input-Natural-gas-95-Percent-Upflow-Horizontal-Forced-Air-Furnace/1002553456
74 Source: https://www.menards.com/main/plumbing/pipe-fittings/pvc-pipe-fittings/pvc-sch-40-plain-end-solid-core-pipe/pvc072000600/p-1444426391701-c-8571.htm?tid=-3946052023881235O&ipos=3
75 Source: https://www.supplyhouse.com/Rheem-SP20897-2-PVC-Concentric-Vent-Termination-Kit
76 Source: https://hvacdirect.com/goodman-3-ton-13-seer-air-conditioner-condenser-with-r410a-refrigerant-gsx130361.html
77 Source: https://hvacdirect.com/goodman-3-ton-16-seer-air-conditioner-condenser-gsx160361.html
78 Source: https://hvacdirect.com/goodman-3-ton-14-seer-air-conditioner-condenser-gsx140361.html
79 Source: https://hvacdirect.com/goodman-3-ton-13-seer-air-conditioner-condenser-with-r410a-refrigerant-gsx130361.html
80 Source: https://hvacdirect.com/goodman-3-ton-14-seer-heat-pump-air-conditioner-system-id694.html
81 Source: https://hvacdirect.com/3-ton-18-seer-goodman-heat-pump-air-conditioner-system-id14356.html
82 Source: https://www.menards.com/main/plumbing/water-heaters/gas-water-heaters/sure-comfort-reg-40-gallon-3-year-34-000-btu-tank-natural-gas-water-heater/scg40t03st34u1/p-1512113333694-c-1541513694149.htm?tid=-6803961517209927632&ipos=4

Tankless gas water heater, 0.82 UEF[83]	EA	$749.00	$174.00	$923.00	$1,006.57	1	$1,006.57
Concentric vent wall termination kit[84]	EA	$68.34		$68.34	$73.76	1	$73.76
Concentric vent 39" extension[85]	EA	$38.03		$38.03	$41.05	1	$41.05
Gas Chimney Vent, 3" dia. (WH connector)[86]	LF	$6.29	$8.00	$14.29	$15.90	(4)	($63.58)
Gas piping, 1/2"[87]	LF	$1.81	$5.25	$7.06	$7.93	(10)	($79.34)
Gas piping, 1"[88]	LF	$2.64	$6.25	$8.89	$9.96	10	$99.62
15-amp circuit, toggle, 40' #14/2 NM[89]	EA	$15.97	$23.50	$39.47	$44.00	1	$44.00
GFCI 15-amp, 1-pole breaker[90]	EA	$36.37		$36.37	$39.26	1	$39.26
Total to Builder							$467.23
Total to Consumer							$548.97

Water Heater option for Electric House: 50 gal Heat Pump Water (HPWH)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
50 gal electric water heater[91]	EA	$499.00		$499.00	$538.59	(1)	($538.59)
HPWH, 50 gal, minimum 2.0 EF[92]	EA	$1,359.00		$1,359.00	$1,466.81	1	$1,466.81
Thermostatic Mixing Valve[93]	EA	$51.56	$16.50	$68.06	$74.44	1	$74.44
Total to Builder							$1,002.67
Total to Consumer							$1,178.09

For the ventilation option, costs were evaluated for the electric and gas house. In climate zone 2 there was an additional cost of improving the infiltration from 5 to 3 ACH50, while the other climate zones were already at 3 ACH50. There was no cost assumed for this option for climate zone 7 because a cost for an ERV from RE139 already met the requirements for this option.

Ventilation Option Gas House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)[94]	EA	$89.05		$89.05	$96.11	(1)	($96.11)
Bath exhaust fan controller[95]	EA	$53.00		$53.00	$57.20	(1)	($57.20)
Bath exhaust fan, standard[96]	EA	$15.39		$15.39	$16.61	1	$16.61
ERV, 100 CFM[97]	EA	$968.99		$968.99	$1,045.86	1	$1,045.86

83 Source: https://www.menards.com/main/plumbing/water-heaters/gas-water-heaters/richmond-reg-mid-efficiency-7-gpm-160-000-btu-tankless-natural-gas-water-heater/rmtg70dvln-1/p-1523946516023-c-1541513694149.htm?tid=-8262144216229885l&ipos=2

84 Source: https://www.supplyhouse.com/Noritz-PVC-2CT-2-PVC-Concentric-Horizontal-Termination?utm_source=bingad&utm_medium=shopping&msclkid=cfe17b3f2b2f169466d21a98cfa62d6e#product-overview

85 Source: https://www.supplyhouse.com/Rinnai-224053-39-Vent-Pipe-Extension-Non-Condensing

86 Source: https://www.grainger.com/product/AMERI-VENT-Gas-Vent-Pipe-3F381

87 Source: https://www.homedepot.com/p/HOME-FLEX-1-2-in-CSST-x-25-ft-Corrugated-Stainless-Steel-Tubing-11-00525/203073939

88 Source: https://www.homedepot.com/p/HOME-FLEX-1-in-CSST-x-150-ft-Corrugated-Stainless-Steel-Tubing-11-010150/204767408

89 Source: https://www.homedepot.com/p/Leviton-15-Amp-Single-Pole-Toggle-Switch-Ivory-R51-01451-02I/100356974

90 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1

91 Source: https://www.homedepot.com/p/Rheem-Performance-50-Gal-Medium-6-Year-4500-4500-Watt-Elements-Electric-Tank-Water-Heater-XE50M06ST45U1/205810732

92 Source: https://www.menards.com/main/plumbing/water-heaters/heat-pump-water-heaters/hybrid-water-heater/10e50-hp530/p-11060051208848487-c-8688.htm?tid=2340475535233083866&ipos=1

93 Source: https://www.lowes.com/pd/Cash-Acme-HG110-D-3-4-in-ID-FNPT-x-3-4-in-OD-FNPT-Brass-Thermostatic-Mixing-Valve/1003193690

94 Source: https://www.homedepot.com/p/Air-King-ENERGY-STAR-Certified-Quiet-90-CFM-Ceiling-Bathroom-Exhaust-Fan-AK90/203258362

95 Source: https://www.hvacquick.com/products/residential/AirFlow-Boosting/Exhaust-Fan-Controls/Fantech-Ventech-ASHRAE-62-2-Controls

96 Source: https://www.homedepot.com/p/Air-King-Advantage-50-CFM-Ceiling-Bathroom-Exhaust-Fan-AS50/203258495

97 Source: https://www.supplyhouse.com/Panasonic-FV-10VEC2-Intelli-Balance-100-Energy-Recovery-Ventilator-Cold-Climate

Installation, labor	HR		$39.90	$39.90	$45.44	2	$90.88
Installation, material	EA	$40.00		$40.00	$43.17	1	$43.17
15-amp circuit, duplex outlet, 20' 14/2 NM[98]	EA	$8.17	$23.50	$31.67	$35.58	1	$35.58
Wire, 14/2, add 20'[99]	LF	$0.38	$1.37	$1.75	$1.97	20	$39.41
GFCI 15-amp 1-pole breaker[100]	EA	$36.37		$36.37	$39.26	1	$39.26
Duct, flexible insulated, 6" dia[101]	LF	$1.60	$2.21	$3.81	$4.24	50	$212.18
Wall cap, 6" dia duct[102]	EA	$7.83	$29.00	$36.83	$41.48	2	$82.95
Total to Builder							$1,452.58
Total to Consumer							$1,706.72

Ventilation Option Electric House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)[103]	EA	$89.05		$89.05	$96.11	(1)	($96.11)
Bath exhaust fan controller[104]	EA	$53.00		$53.00	$57.20	(1)	($57.20)
Bath exhaust fan, standard[105]	EA	$15.39		$15.39	$16.61	1	$16.61
ERV, 100 CFM[106]	EA	$968.99		$968.99	$1,045.86	1	$1,045.86
Installation, labor	HR		$39.90	$39.90	$45.44	2	$90.88
Installation, material	EA	$40.00		$40.00	$43.17	1	$43.17
15-amp circuit, duplex outlet, 20' 14/2 NM[107]	EA	$8.17	$23.50	$31.67	$35.58	1	$35.58
Wire, 14/2, add 20'[108]	LF	$0.38	$1.37	$1.75	$1.97	2	$39.41
GFCI 15-amp 1-pole breaker[109]	EA	$36.37		$36.37	$39.26	1	$39.26
Duct, flexible insulated, 6" dia[110]	LF	$1.60	$2.21	$3.81	$4.24	50	$212.18
Wall cap, 6" dia duct[111]	EA	$7.83	$29.00	$36.83	$41.48	2	$82.95
Total to Builder							$1,452.58
Total to Consumer							$1,706.72

For the ventilation option in climate zone 2 there was an additional cost of improving the infiltration from 5 to 3 ACH50. Decreasing infiltration generally includes additional labor time to complete air sealing details with materials on site. NREL's National Residential Efficiency Measure Database estimates that as a *retrofit* measure improving infiltration from 5 to 3 ACH 50 will cost between $0.22/SF and $0.82/SF, with an average of $0.52/SF. Note that these are costs for a retrofit, and air sealing new construction can be performed at a

98 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1

99 Source: https://www.grainger.com/product/ROMEX-Nonmetallic-Building-Cable-4WZT4

100 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1

101 Source: https://www.homedepot.com/p/Master-Flow-6-in-x-25-ft-Insulated-Flexible-Duct-R6-Silver-Jacket-F6IFD6X300/100396935

102 Source: https://www.supplyhouse.com/Lambro-Industries-361W-6-White-Plastic-Louvered-Wall-Vent

103 Source: https://www.homedepot.com/p/Air-King-ENERGY-STAR-Certified-Quiet-90-CFM-Ceiling-Bathroom-Exhaust-Fan-AK90/203258362

104 Source: https://www.hvacquick.com/products/residential/AirFlow-Boosting/Exhaust-Fan-Controls/Fantech-Ventech-ASHRAE-62-2-Controls

105 Source: https://www.homedepot.com/p/Air-King-Advantage-50-CFM-Ceiling-Bathroom-Exhaust-Fan-AS50/203258495

106 Source: https://www.supplyhouse.com/Panasonic-FV-10VEC2-Intelli-Balance-100-Energy-Recovery-Ventilator-Cold-Climate

107 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1

108 Source: https://www.grainger.com/product/ROMEX-Nonmetallic-Building-Cable-4WZT4

109 Source: https://www.menards.com/main/electrical/circuit-protection-power-distribution/circuit-breakers/square-d-trade-homeline-trade-1-pole-gfci-circuit-breaker/hom115gficp/p-1444444038687-c-1489583170892.htm?tid=7535224849621723670&ipos=1

110 Source: https://www.homedepot.com/p/Master-Flow-6-in-x-25-ft-Insulated-Flexible-Duct-R6-Silver-Jacket-F6IFD6X300/100396935

111 Source: https://www.supplyhouse.com/Lambro-Industries-361W-6-White-Plastic-Louvered-Wall-Vent

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substantially lower cost. NREL's BEopt 2.8.0.0 includes a cost for air sealing new construction, which shows an incremental cost of $0.105/SF for this level of improvement, which was ultimately used in this analysis.

Ventilation Option Electric House in CZ 2

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Associated ERV cost to builder from above							$1,452.58
Improve ACH50 from 5 to 3, estimate[112]	SF	$0	$0.105	$0.10	$0.12	2500	$298.14
Total to Builder							$1,750.72
Total to Consumer							$2,057.02

For the ventilation option, conditioned basements and conditioned crawlspaces were not evaluated, typically they would include the air handlers and ductwork, so there would be no incremental cost for homes with these foundations to meet this option. Slab homes were considered to meet the requirement by burying ducts per section R403.3.3, which required at least R-19 insulation above the duct, and R-13 insulation wrapped around the duct in climate zones 1 through 3. The air handler was located in a newly constructed mechanical closet to meet the requirements of R403.3.2.

Duct Option: Slab House, Buried Ducts, CZ 2-3

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
R13 duct: add FSK min R5 over R8 duct[113]	SF	$0.31	$1.70		$2.01	$2.15	680	$1,461.21
Add ceiling insulation, R19 blown[114]	SF	$0.17	$0.61	$0.36	$1.14	$1.24	340	$421.79
Mechanical closet, 3'x4', partition wall	LF	$7.40	$4.89		$12.29	$12.68	10	$126.78
Mechanical closet, drywall, finished[115]	SF	$0.26	$0.61		$0.87	$0.92	140	$128.40
Mechanical closet door[116]	EA	$53.73	$34.50		$88.23	$90.97	1	$90.97
Delete attic platform decking, 3/4, 8'x8'[117]	SF	$1.46	$0.38		$1.84	$1.87	(64)	($119.41)
Delete attic platform joist framing, 2x12[118]	LF	$1.60	$0.58		$2.18	$2.22	(40)	($88.87)
Total to Builder								$2,020.87
Total to Consumer								$2,374.43

112 Source: BEopt 2.8.0.0 https://www.nrel.gov/buildings/beopt.html
113 Source: https://www.plumbersstock.com/qflex-dwr83048050-2inx48x50ft-r8-ductwrap.html
114 Source: https://www.menards.com/main/building-materials/insulation/loose-fill-insulation/insulmax-reg-blow-in-cellulose-insulation/1611640/p-1520836262471-c-5777.htm?tid=4389096187601806274&ipos=1
115 Source: https://www.menards.com/main/building-materials/drywall/drywall-sheets/1-2-x-4-x-8-lightweight-drywall/1311223/p-1444421962026-c-5656.htm?tid=-5114540465575422448&ipos=3
116 Source: https://www.lowes.com/pd/Masonite-Left-Hand-Outswing-Primed-Fiberglass-Prehung-Entry-Door-with-Insulating-Core-Common-32-in-x-80-in-Actual-33-5-in-x-80-375-in/1000054363
117 Source: https://www.lowes.com/pd/23-32-Category-SYP-Rated/1003124582
118 Source: https://www.lowes.com/pd/Top-Choice-2-in-x-12-in-x-12-ft-Southern-Yellow-Pine-Lumber-Common-1-5-in-x-11-25-in-x-12-ft-Actual/1000009756

Duct Option: Slab House, Buried Ducts, CZ 4-7

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Add ceiling insulation, R19 blown[119]	SF	$0.17	$0.61	$0.36	$1.14	$1.24	340	$421.79
Mechanical closet, 3'x4', partition wall	LF	$7.40	$4.89		$12.29	$12.68	10	$126.78
Mechanical closet, drywall, finished[120]	SF	$0.26	$0.61		$0.87	$0.92	140	$128.40
Mechanical closet door[121]	EA	$53.73	$34.50		$88.23	$90.97	1	$90.97
Delete attic platform decking, 3/4, 8'x8'[122]	SF	$1.46	$0.38		$1.84	$1.87	(64)	($119.41)
Delete attic platform joist framing, 2x12[123]	LF	$1.60	$0.58		$2.18	$2.22	(40)	($88.87)
Total to Builder								$559.65
Total to Consumer								$657.57

For the ventilation option, crawl space homes were converted from a vented to an unvented crawlspace, which resulted in a decrease in construction costs.

Duct Option: Convert Crawlspace from Vented to Unvented, CZ 3

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Floor insulation, R19[124]	SF	$0.57	$0.49		$1.06	$1.10	(1,875)	($2,053.44)
Wall insulation, foil-faced polyiso, 1", R6[125]	SF	$0.53	$0.37		$0.90	$0.93	1,000	$929.98
Foundation vents[126]	EA	$7.98			$7.98	$7.98	(6)	($47.88)
Class 1 vapor retarder on ground[127]	SF	$0.08	$0.08		$0.16	$0.17	1,875	$321.24
Supply duct, 38 cfm (1 cfm/50sf)	EA				$125.00	$125.00	1	$125.00
Transfer grille[128]	EA	$22.48	$13.30		$35.78	$36.84	1	$36.84
Total to Builder								($688.27)
Total to Consumer								($808.69)

Duct Option: Convert Crawlspace from Vented to Unvented, CZ 4

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Floor insulation, R19[129]	SF	$0.57	$0.49		$1.06	$1.10	(1,875)	($2,053.44)

119 Source: https://www.menards.com/main/building-materials/insulation/loose-fill-insulation/insulmax-reg-blow-in-cellulose-insulation/1611640/p-1520836262471-c-5777.htm?tid=4389096187601806274&ipos=1
120 Source: https://www.menards.com/main/building-materials/drywall/drywall-sheets/1-2-x-4-x-8-lightweight-drywall/1311223/p-1444421962026-c-5656.htm?tid=-5114540465575422448&ipos=3
121 Source: https://www.lowes.com/pd/Masonite-Left-Hand-Outswing-Primed-Fiberglass-Prehung-Entry-Door-with-Insulating-Core-Common-32-in-x-80-in-Actual-33-5-in-x-80-375-in/1000054363
122 Source: https://www.lowes.com/pd/23-32-Category-SYP-Rated/1003124582
123 Source: https://www.lowes.com/pd/Top-Choice-2-in-x-12-in-x-12-ft-Southern-Yellow-Pine-Lumber-Common-1-5-in-x-11-25-in-x-12-ft-Actual/1000009756
124 Source: https://www.homedepot.com/p/Knauf-Insulation-R-19-EcoBatt-Kraft-Faced-Fiberglass-Insulation-Batt-6-1-4-in-x-15-in-x-94-in-12-Bags-690982/313646748
125 Source: https://www.lowes.com/pd/Common-1-in-x-4-ft-x-8-ft-Actual-0-9375-in-x-3-875-ft-x-7-875-ft-R-Expanded-Polystyrene-Foam-Board-Insulation/3365576
126 Source: https://www.lowes.com/pd/Master-Flow-16-87-in-x-7-5-in-Plastic-Foundation-Vent/999972074
127 Source: https://www.lowes.com/pd/BARRICADE-10-ft-x-100-ft-Clear-6-mil-Plastic-Sheeting/1000158151
128 Source: https://www.homedepot.com/p/Everbilt-4-in-x-12-in-Heavy-Duty-Steel-Floor-Return-Air-Grille-in-Brown-E154R-04X12/300713055?source=shoppingads&locale=en-US
129 Source: https://www.homedepot.com/p/Knauf-Insulation-R-19-EcoBatt-Kraft-Faced-Fiberglass-Insulation-Batt-6-1-4-in-x-15-in-x-94-in-12-Bags-690982/313646748

Wall insulation, foil-faced polyiso, 2", R12[130]	SF	$1.16	$0.40		$1.56	$1.59	1,000	$929.98
Foundation vents[131]	EA	$7.98			$7.98	$7.98	(6)	($47.88)
Class 1 vapor retarder on ground[132]	SF	$0.08	$0.08		$0.16	$0.16	1,875	$321.24
Supply duct, 38 cfm (1 cfm/50sf)	EA				$125.00	$125.00	1	$125.00
Transfer grille[133]	EA	$22.48	$13.30		$35.78	$36.84	1	$36.84
Total to Builder								($30.89)
Total to Consumer								($36.30)

130 Source: https://www.lowes.com/pd/Johns-Manville-Common-2-in-x-4-ft-x-8-ft-Actual-2-in-x-4-ft-x-8-ft-AP-Foil-1-R-13-Faced-Polyisocyanurate-Foam-Board-Insulation/3851107
131 Source: https://www.lowes.com/pd/Master-Flow-16-87-in-x-7-5-in-Plastic-Foundation-Vent/999972074
132 Source: https://www.lowes.com/pd/BARRICADE-10-ft-x-100-ft-Clear-6-mil-Plastic-Sheeting/1000158151
133 Source: https://www.homedepot.com/p/Everbilt-4-in-x-12-in-Heavy-Duty-Steel-Floor-Return-Air-Grille-in-Brown-E154R-04X12/300713055?source=shoppingads&locale=en-US

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CE40.2

Reference Code Section

R303.1.2 Insulation mark installation

Summary of Code Change:

This code change requires that for insulation materials without an observable R-value (e.g., blown-in insulation), that the R-value must be left after installation in a conspicuous location in the building.

Cost Implication of the Code Change

This code change will not change the cost of construction. Other code requirements in this same section already require the R-value to be known or displayed and this change mostly clarifies when that data must be communicated. Therefore, no cost impact is assumed for the reference home.

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CE151.2

Reference Code Section

R202 Defined terms (new); R403.3.1 Ducts located outside conditioned space

Summary of Code Change:

This code change adds a definition for Thermal Distribution Efficiency (TDE) and requirements for ducts buried underneath buildings.

Cost Implication of the Code Change

This code change may decrease the cost of construction in limited cases, but it will not impact any homes in this analysis. Therefore, no cost impact is assumed for the reference home.

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APPENDIX B: CONSTRUCTION COST BY CLIMATE ZONE

Proposal	Description	Affected CZ	Reference House	CZ 2 Phoenix Mass (30%) Electric Slab 100%	CZ 2 Phoenix Frame (70%) Electric Slab 100%
RE7	Lighting: revised definition of high-efficacy	All	$0		
RE18, RE20, RE21	Certificate: additional info	All	$0		
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742		
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680		
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709		
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709		
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226	$226	$226
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198		
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA		
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$67		
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0		
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0		
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6	$6	$6
RE49	Baffles at attic access	All	$0		
RE72	Air seal narrow framing cavities	All	$0		

RE82	Air seal rim (basement; unvented crawlspace	All	$0		
RE82	Air seal rim (slab, vented crawlspace)	All	$0		
RE96	House tightness, allows trade-off for performance path	All	$0		
RE103	Air seal electrical & communication outlet boxes	All	$0		
RE106	Thermostat: requires 7-day programming	All	$0		
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0		
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742		
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33	$33
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		
RE148	Lighting, commercial	All	NA		
RE149	Lighting: exterior controls	All	$0		
RE151	Performance path backstop: 2009 IECC	All	NA		
RE178	Performance path ventilation type to match proposed	All	NA		
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0		
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA		
	Sub-total without additional efficiency package option			$297	$297
	Weighted average, foundations				$297
			Nat Ave	CZ 2	
	Without additional efficiency package options		$1,373	$297	
RE209	HVAC option		$1,900	$2,567	
RE209	Water Heater option		$901	$1,178	
RE209	Ventilation option		$1,788	$2,057	

RE209	Duct option, slab house		$1,870	$2,374
RE209	Duct option, vented crawlspace house			
	Total with HVAC option		$3,273	$2,864
	Total with Water Heater option		$2,274	$1,475
	Total with Ventilation option		$3,161	$2,354
	Total with Duct option, slab house		$3,243	$2,672
	Total with Duct option, vented crawlspace house			

Proposal	Description	Affected CZ	Reference House	CZ 3					
				Memphis					
				Mass (10%)			Frame (90%)		
				Electric			Electric		
				Slab	Base ment	Crawl	Slab	Base ment	Crawl
				75%	10%	15%	75%	10%	15%
RE7	Lighting: revised definition of high-efficacy	All	$0						
RE18, RE20, RE21	Certificate: additional info	All	$0						
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742						
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680						
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709	$709			$709		
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709						
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226	$226	$226	$226	$226	$226	$226
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198						
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA						

RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$67	$67	$67	$67	$67	$67	$67
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0						
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0						
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6	$6	$6	$6	$6	$6	$6
RE49	Baffles at attic access	All	$0						
RE72	Air seal narrow framing cavities	All	$0						
RE82	Air seal rim (basement; unvented crawlspace	All	$0						
RE82	Air seal rim (slab, vented crawlspace)	All	$0						
RE96	House tightness, allows trade-off for performance path	All	$0						
RE103	Air seal electrical & communication outlet boxes	All	$0						
RE106	Thermostat: requires 7-day programming	All	$0						
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47			$47	
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0						
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742						
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33			$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42		$42	$42
RE148	Lighting, commercial	All	NA						
RE149	Lighting: exterior controls	All	$0						

RE151	Performance path backstop: 2009 IECC	All	NA						
RE178	Performance path ventilation type to match proposed	All	NA						
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0						
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA						
	Sub-total without additional efficiency package option			$1,073	$419	$372	$1,073	$419	$372
	Weighted average, foundations			$1,347			$1,347		
			Nat Ave	CZ 3					
	Without additional efficiency package options		$1,373	$902					
RE209	HVAC option		$1,900	$2,567					
RE209	Water Heater option		$901	$1,178					
RE209	Ventilation option		$1,788	$1,707					
RE209	Duct option, slab house		$1,870	$2,545					
RE209	Duct option, vented crawlspace house			($1,339)					
	Total with HVAC option		$3,273	$3,469					
	Total with Water Heater option		$2,274	$2,080					
	Total with Ventilation option		$3,161	$2,609					
	Total with Duct option, slab house		$3,243	$3,447					
	Total with Duct option, vented crawlspace house			($437)					

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Proposal	Description	Affected CZ	Reference House	CZ 4 Baltimore Frame Wall Gas Slab 20%	CZ 4 Baltimore Frame Wall Gas Basement 60%	CZ 4 Baltimore Frame Wall Gas Crawl 20%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18, RE20, RE21	Certificate: additional info	All	$0			
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742	$1,742	$1,742	$1,742
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680			
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709			
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709	$709		
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226			
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198	$198	$198	$198
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA			
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$67	$67	$67	$67
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0			
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0			
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6	$6	$6	$6
RE49	Baffles at attic access	All	$0			
RE72	Air seal narrow framing cavities	All	$0			
RE82	Air seal rim (basement; unvented crawlspace	All	$0			

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RE82	Air seal rim (slab, vented crawlspace)	All	$0			
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$0			
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47	
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0			
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742			
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$0			
RE151	Performance path backstop: 2009 IECC	All	NA			
RE178	Performance path ventilation type to match proposed	All	NA			
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0			
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			
	Sub-total without additional efficiency package option			$2,786	$2,133	$2,086
	Weighted average, foundations					$2,254
			Nat Ave	CZ 4		
	Without additional efficiency package options		$1,373	$2,254		
RE209	HVAC option		$1,900	$952		
RE209	Water Heater option		$901	$549		
RE209	Ventilation option		$1,788	$1,707		
RE209	Duct option, slab house		$1,870	$1,190		

RE209	Duct option, vented crawlspace house			($205)
	Total with HVAC option		$3,273	$3,206
	Total with Water Heater option		$2,274	$2,803
	Total with Ventilation option		$3,161	$3,961
	Total with Duct option, slab house		$3,243	$3,444
	Total with Duct option, vented crawlspace house			$2,049

Proposal	**Description**	Affected CZ	Reference House	CZ 5 Chicago Frame Wall Gas		
				Slab	Baseme nt	Crawl
				15%	70%	15%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18, RE20, RE21	Certificate: additional info	All	$0			
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742			
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680	$2,680	$2,680	$2,680
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709			
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709	$709		
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226			
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198	$198	$198	$198
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA			
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$67			

RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0			
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0			
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6	$6	$6	
RE49	Baffles at attic access	All	$0			
RE72	Air seal narrow framing cavities	All	$0			
RE82	Air seal rim (basement; unvented crawlspace	All	$0			
RE82	Air seal rim (slab, vented crawlspace)	All	$0			
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$0			
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47	$47
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0			
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742			
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$0			
RE151	Performance path backstop: 2009 IECC	All	NA			
RE178	Performance path ventilation type to match proposed	All	NA			
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0			
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			

	Sub-total without additional efficiency package option			$3,658	$3,004	$3,004
	Weighted average, foundations					$3,102
			Nat Ave	CZ 5		
	Without additional efficiency package options		$1,373	$3,102		
RE209	HVAC option		$1,900	$1,143		
RE209	Water Heater option		$901	$549		
RE209	Ventilation option		$1,788	$1,707		
RE209	Duct option, slab house		$1,870	$1,213		
RE209	Duct option, vented crawlspace house					
	Total with HVAC option		$3,273	$4,245		
	Total with Water Heater option		$2,274	$3,651		
	Total with Ventilation option		$3,161	$4,809		
	Total with Duct option, slab house		$3,243	$4,315		
	Total with Duct option, vented crawlspace house					

Proposal	Description	Affected CZ	Reference House	CZ 6		
				Helena		
				Frame Wall		
				Gas		
				Slab	Basement	Crawl
				5%	90%	5%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18, RE20, RE21	Certificate: additional info	All	$0			
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742			
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680			
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709			
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709			
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226			
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198	$198	$198	$198
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA			
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$67			
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0			
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0			
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6	$6	$6	$6
RE49	Baffles at attic access	All	$0			
RE72	Air seal narrow framing cavities	All	$0			
RE82	Air seal rim (basement; unvented crawlspace	All	$0			

RE82	Air seal rim (slab, vented crawlspace)	All	$0			
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$0			
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47	$47
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0			
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742			
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$0			
RE151	Performance path backstop: 2009 IECC	All	NA			
RE178	Performance path ventilation type to match proposed	All	NA			
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0			
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			
	Sub-total without additional efficiency package option			$269	$324	$324
	Weighted average, foundations					$321
			Nat Ave	CZ 6		
	Without additional efficiency package options		$1,373	$321		
RE209	HVAC option		$1,900	$1,143		
RE209	Water Heater option		$901	$549		
RE209	Ventilation option		$1,788	$1,707		
RE209	Duct option, slab house		$1,870	$605		

RE209	Duct option, vented crawlspace house			
	Total with HVAC option		$3,273	$1,464
	Total with Water Heater option		$2,274	$870
	Total with Ventilation option		$3,161	$2,028
	Total with Duct option, slab house		$3,243	$926
	Total with Duct option, vented crawlspace house			

				CZ 7		
				Duluth		
				Frame Wall		
				Gas		
				Slab	Basement	Crawl
Proposal	**Description**	Affected CZ	Reference House	30%	5%	65%
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18, RE20, RE21	Certificate: additional info	All	$0			
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	4	$1,742			
RE29	Frame wall, c.i..: R5 to R10 (2x4); R0 to R5 (2x6)	5	$2,680			
RE32	Slab edge: NR to R10/2 (CZ3)	3	$709			
RE32	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$709			
RE33, RE36	Ceiling insulation R38 to R49	2-3	$226			
RE33, RE36	Ceiling insulation R49 to R60	4-7	$198	$198	$198	$198
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA			
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$67			
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0			

RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0			
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$6	$6	$6	$6
RE49	Baffles at attic access	All	$0			
RE72	Air seal narrow framing cavities	All	$0			
RE82	Air seal rim (basement; unvented crawlspace	All	$0			
RE82	Air seal rim (slab, vented crawlspace)	All	$0			
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$0			
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$47		$47	$47
RE130	Adds requirement to test whole-dwelling ventilation	All	$31	$31	$31	$31
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$0			
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$1,742	$1,742	$1,742	$1,742
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$33	$33		
RE145	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$42		$42	$42
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$0			
RE151	Performance path backstop: 2009 IECC	All	NA			
RE178	Performance path ventilation type to match proposed	All	NA			
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$0			
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			
	Sub-total without additional efficiency package option			$2,011	$2,066	$2,066

	Weighted average, foundations			$2,050
			Nat Ave	CZ 7
	Without additional efficiency package options		$1,373	$2,050
RE209	HVAC option		$1,900	$1,143
RE209	Water Heater option		$901	$549
RE209	Ventilation option		$1,788	$0
RE209	Duct option, slab house		$1,870	$619
RE209	Duct option, vented crawlspace house			
	Total with HVAC option		$3,273	$3,192
	Total with Water Heater option		$2,274	$2,599
	Total with Ventilation option		$3,161	$2,050
	Total with Duct option, slab house		$3,243	$2,669
	Total with Duct option, vented crawlspace house			

APPENDIX C: LOCATION ADJUSTMENT FACTORS

State	City	Cost Adjustment Factor	State	City	Cost Adjustment Factor
Alabama	Birmingham	0.84	Montana	Billings	0.89
Alabama	Mobile	0.83	Nebraska	Omaha	0.90
Alaska	Fairbanks	1.21	Nevada	Las Vegas	1.03
Arizona	Phoenix	0.84	New Hampshire	Portsmouth	0.95
Arizona	Tucson	0.84	New Jersey	Jersey City	1.18
Arkansas	Little Rock	0.83	New Mexico	Albuquerque	0.86
California	Alhambra	1.15	New York	Long Island City	1.36
California	Los Angeles	1.15	New York	Syracuse	0.99
California	Riverside	1.13	North Carolina	Charlotte	0.99
California	Stockton	1.20	North Carolina	Hickory	0.93
Colorado	Boulder	0.90	North Carolina	Raleigh	0.94
Colorado	Colorado Springs	0.87	North Dakota	Fargo	0.87
Colorado	Denver	0.91	Ohio	Columbus	0.91
Connecticut	New Haven	1.10	Oklahoma	Oklahoma City	0.84
Delaware	Dover	1.02	Oklahoma	Tulsa	0.83
District of Columbia	Washington, D.C.	0.92	Oregon	Bend	1.02
Florida	Fort Meyers	0.79	Pennsylvania	Norristown	1.05
Florida	Miami	0.83	Pennsylvania	State College	0.94
Florida	Orlando	0.82	Rhode Island	Providence	1.09
Florida	Tampa	0.81	South Carolina	Greenville	0.97
Georgia	Atlanta	0.90	South Dakota	Sioux Falls	0.92
Hawaii	Honolulu	1.22	Tennessee	Memphis	0.87
Idaho	Boise	0.89	Texas	Austin	0.80
Illinois	Chicago	1.25	Texas	Dallas	0.84
Indiana	Indianapolis	0.92	Texas	Houston	0.84
Iowa	Des Moines	0.92	Texas	San Antonio	0.83
Kansas	Wichita	0.81	Utah	Ogden	0.84
Kentucky	Louisville	0.89	Utah	Provo	0.85
Louisiana	Baton Rouge	0.85	Utah	Salt Lake City	0.85
Maine	Portland	0.94	Vermont	Burlington	0.95
Maryland	Baltimore	0.93	Virginia	Fairfax	1.00
Massachusetts	Boston	1.18	Virginia	Winchester	0.99
Michigan	Ann Arbor	0.99	Washington	Tacoma	1.05
Minnesota	Minneapolis	1.09	West Virginia	Charleston	0.94
Mississippi	Biloxi	0.83	Wisconsin	La Crosse	0.95
Missouri	Springfield	0.86	Wyoming	Casper	0.85

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APPENDIX D: 2021 IECC INSULATION AND FENESTRATION CHANGES

The table below shows the insulation minimum R-values and fenestration requirements for the 2021 IECC, with redline text indicating changes from the 2018 IECC.

Insulation Minimum R-value and Fenestration Requirements. Source: adapted from the 2018 and 2021 IECC

Climate Zone	Fenestration U-factor	Skylight U-factor	Fenestration SHGC	Ceiling R-value	Frame Wall R-value	Mass Wall R-value	Floor R-value	Basement wall R-value*	Slab R-value & depth	Crawl Space wall R-value*
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	~~38~~ 49	13	4/6	13	0	0	0
3	~~0.32~~ 0.30	0.55	0.25	~~38~~ 49	20	8/13	19	5/13	~~0~~ 10, 2 ft	5/13
4 except Marine	~~0.32~~ 0.30	0.55	0.40	~~49~~ 60	~~20~~ 20+5	8/13	19	10/13	~~10, 2 ft~~ 10, 4 ft	10/13
5 and Marine 4	0.30	0.55	~~NR~~ 0.40	~~49~~ 60	~~20~~ 20+5	13/17	30	15/19	~~10, 2 ft~~ 10, 4 ft	15/19
6	0.30	0.55	NR	~~49~~ 60	20+5	15/20	30	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	~~49~~ 60	20+5	19/21	38	15/19	10, 4 ft	15/19

* Cavity insulation / continuous insulation

APPENDIX E: ENERGY USE BY CLIMATE ZONE

CZ	Fuel	Foundations	Wall	Code	Efficiency Option	kWh/yr	thrm/yr	$/yr
2	Electric	Slab	Mass	2018	Base	17,107	0	$2,225.62
2	Electric	Slab	Frame	2018	Base	17,087	0	$2,223.02
2	Electric	Slab	Mass	2018	2021 ceiling insulation	17,052	0	$2,218.47
2	Electric	Slab	Frame	2018	2021 ceiling insulation	17,028	0	$2,215.34
2	Electric	Slab	Mass	2021	Base	16,638	0	$2,164.60
2	Electric	Slab	Frame	2021	Base	16,615	0	$2,161.61
2	Electric	Slab	Mass	2021	HVAC option	15,727	0	$2,046.08
2	Electric	Slab	Frame	2021	HVAC option	15,715	0	$2,044.52
2	Electric	Slab	Mass	2021	Water Heater option	15,618	0	$2,031.90
2	Electric	Slab	Frame	2021	Water Heater option	15,589	0	$2,028.13
2	Electric	Slab	Mass	2021	Ventilation option	16,506	0	$2,147.43
2	Electric	Slab	Frame	2021	Ventilation option	16,465	0	$2,142.10
2	Electric	Slab	Mass	2021	Duct option	15,768	0	$2,051.42
2	Electric	Slab	Frame	2021	Duct option	15,715	0	$2,044.52
3	Electric	Slab	Mass	2018	Base	15,618	0	$2,031.90
3	Electric	Slab	Frame	2018	Base	15,557	0	$2,023.97
3	Electric	Cond Basement	Mass	2018	Base	16,612	0	$2,161.22
3	Electric	Cond Basement	Frame	2018	Base	16,547	0	$2,152.76
3	Electric	Vented Crawl	Mass	2018	Base	15,144	0	$1,970.23
3	Electric	Vented Crawl	Frame	2018	Base	15,056	0	$1,958.79
3	Electric	Slab	Mass	2018	2021 ceiling insulation	15,536	0	$2,021.23
3	Electric	Slab	Frame	2018	2021 ceiling insulation	15,472	0	$2,012.91

3	Electric	Cond Basement	Mass	2018	2021 ceiling insulation	16,521	0	$2,149.38
3	Electric	Cond Basement	Frame	2018	2021 ceiling insulation	16,451	0	$2,140.28
3	Electric	Vented Crawl	Mass	2018	2021 ceiling insulation	15,053	0	$1,958.40
3	Electric	Vented Crawl	Frame	2018	2021 ceiling insulation	14,959	0	$1,946.17
3	Electric	Slab	Mass	2018	2021 slab insulation	14,938	0	$1,943.43
3	Electric	Slab	Frame	2018	2021 slab insulation	14,877	0	$1,935.50
3	Electric	Slab	Mass	2018	2021 window U-Factor	15,566	0	$2,025.14
3	Electric	Slab	Frame	2018	2021 window U-Factor	15,501	0	$2,016.68
3	Electric	Cond Basement	Mass	2018	2021 window U-Factor	16,553	0	$2,153.55
3	Electric	Cond Basement	Frame	2018	2021 window U-Factor	16,489	0	$2,145.22
3	Electric	Vented Crawl	Mass	2018	2021 window U-Factor	15,091	0	$1,963.34
3	Electric	Vented Crawl	Frame	2018	2021 window U-Factor	14,994	0	$1,950.72
3	Electric	Slab	Mass	2021	Base	14,408	0	$1,874.48
3	Electric	Slab	Frame	2021	Base	14,344	0	$1,866.15
3	Electric	Cond Basement	Mass	2021	Base	15,903	0	$2,068.98
3	Electric	Cond Basement	Frame	2021	Base	15,832	0	$2,059.74
3	Electric	Vented Crawl	Mass	2021	Base	14,610	0	$1,900.76
3	Electric	Vented Crawl	Frame	2021	Base	14,519	0	$1,888.92
3	Electric	Slab	Mass	2021	HVAC option	13,485	0	$1,754.40
3	Electric	Slab	Frame	2021	HVAC option	13,450	0	$1,749.85
3	Electric	Cond Basement	Mass	2021	HVAC option	14,824	0	$1,928.60
3	Electric	Cond Basement	Frame	2021	HVAC option	14,786	0	$1,923.66
3	Electric	Vented Crawl	Mass	2021	HVAC option	13,561	0	$1,764.29
3	Electric	Vented Crawl	Frame	2021	HVAC option	13,502	0	$1,756.61

3	Electric	Slab	Mass	2021	Water Heater option	13,277	0	$1,727.34
3	Electric	Slab	Frame	2021	Water Heater option	13,212	0	$1,718.88
3	Electric	Cond Basement	Mass	2021	Water Heater option	14,742	0	$1,917.93
3	Electric	Cond Basement	Frame	2021	Water Heater option	14,669	0	$1,908.44
3	Electric	Vented Crawl	Mass	2021	Water Heater option	13,470	0	$1,752.45
3	Electric	Vented Crawl	Frame	2021	Water Heater option	13,382	0	$1,741.00
3	Electric	Slab	Mass	2021	Ventilation option	14,326	0	$1,863.81
3	Electric	Slab	Frame	2021	Ventilation option	14,259	0	$1,855.10
3	Electric	Cond Basement	Mass	2021	Ventilation option	15,727	0	$2,046.08
3	Electric	Cond Basement	Frame	2021	Ventilation option	15,651	0	$2,036.20
3	Electric	Vented Crawl	Mass	2021	Ventilation option	14,446	0	$1,879.42
3	Electric	Vented Crawl	Frame	2021	Ventilation option	14,346	0	$1,866.41
3	Electric	Slab	Mass	2021	Duct option	13,816	0	$1,797.46
3	Electric	Slab	Frame	2021	Duct option	13,749	0	$1,788.74
3	Electric	Vented Crawl	Mass	2021	Duct option	14,273	0	$1,856.92
3	Electric	Vented Crawl	Frame	2021	Duct option	14,174	0	$1,844.04
4	Gas	Slab	Frame	2018	Base	8,262	697	$1,807.43
4	Gas	Cond Basement	Frame	2018	Base	9,848	696	$2,012.72
4	Gas	Vented Crawl	Frame	2018	Base	8,669	665	$1,826.75
4	Gas	Slab	Frame	2018	2021 ceiling insulation	8,244	690	$1,797.73
4	Gas	Cond Basement	Frame	2018	2021 ceiling insulation	9,833	689	$2,003.41
4	Gas	Vented Crawl	Frame	2018	2021 ceiling insulation	8,652	659	$1,818.23
4	Gas	Slab	Frame	2018	2021 slab insulation	8,180	674	$1,772.59
4	Gas	Slab	Frame	2018	2021 wall cont. insulation	8,177	661	$1,758.54

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4	Gas	Cond Basement	Frame	2018	2021 wall cont. insulation	9,763	660	$1,963.83
4	Gas	Vented Crawl	Frame	2018	2021 wall cont. insulation	8,590	629	$1,778.64
4	Gas	Slab	Frame	2018	2021 window U-Factor	8,256	687	$1,796.14
4	Gas	Cond Basement	Frame	2018	2021 window U-Factor	9,848	686	$2,002.21
4	Gas	Vented Crawl	Frame	2018	2021 window U-Factor	8,666	656	$1,816.90
4	Gas	Slab	Frame	2021	Base	7,673	626	$1,656.18
4	Gas	Cond Basement	Frame	2021	Base	9,159	649	$1,873.68
4	Gas	Vented Crawl	Frame	2021	Base	8,174	616	$1,710.85
4	Gas	Slab	Frame	2021	HVAC option	7,348	565	$1,549.79
4	Gas	Cond Basement	Frame	2021	HVAC option	8,795	580	$1,753.81
4	Gas	Vented Crawl	Frame	2021	HVAC option	7,761	552	$1,589.86
4	Gas	Slab	Frame	2021	Water Heater option	7,629	601	$1,624.00
4	Gas	Cond Basement	Frame	2021	Water Heater option	9,144	614	$1,835.00
4	Gas	Vented Crawl	Frame	2021	Water Heater option	8,126	591	$1,678.00
4	Gas	Slab	Frame	2021	Ventilation option	7,931	586	$1,647.71
4	Gas	Cond Basement	Frame	2021	Ventilation option	9,481	584	$1,847.26
4	Gas	Vented Crawl	Frame	2021	Ventilation option	8,420	575	$1,699.77
4	Gas	Slab	Frame	2021	Duct option	7,495	581	$1,585.73
4	Gas	Vented Crawl	Frame	2021	Duct option	7,732	607	$1,643.89
5	Gas	Slab	Frame	2018	Base	7,666	1,102	$2,156.00
5	Gas	Cond Basement	Frame	2018	Base	9,297	1,089	$2,354.08
5	Gas	Cond Crawl	Frame	2018	Base	7,720	999	$2,054.32
5	Gas	Slab	Frame	2018	2021 ceiling insulation	7,691	1,090	$2,146.19
5	Gas	Cond Basement	Frame	2018	2021 ceiling insulation	9,285	1,080	$2,343.06

5	Gas	Cond Crawl	Frame	2018	2021 ceiling insulation	7,702	991	$2,043.57
5	Gas	Slab	Frame	2018	2021 slab insulation	7,647	1,071	$2,120.50
5	Gas	Slab	Frame	2018	2021 wall cont. insulation	7,617	1,049	$2,093.47
5	Gas	Cond Basement	Frame	2018	2021 wall cont. insulation	9,209	1,040	$2,291.13
5	Gas	Cond Crawl	Frame	2018	2021 wall cont. insulation	7,635	952	$1,993.87
5	Gas	Slab	Frame	2021	Base	7,142	1,018	$1,999.09
5	Gas	Cond Basement	Frame	2021	Base	8,614	1,037	$2,210.57
5	Gas	Cond Crawl	Frame	2021	Base	7,216	947	$1,934.10
5	Gas	Slab	Frame	2021	HVAC option	6,770	898	$1,824.58
5	Gas	Cond Basement	Frame	2021	HVAC option	8,209	914	$2,028.60
5	Gas	Cond Crawl	Frame	2021	HVAC option	6,838	837	$1,769.31
5	Gas	Slab	Frame	2021	Water Heater option	7,137	998	$1,977.00
5	Gas	Cond Basement	Frame	2021	Water Heater option	8,618	1,003	$2,175.00
5	Gas	Cond Crawl	Frame	2021	Water Heater option	7,211	925	$1,910.00
5	Gas	Slab	Frame	2021	Ventilation option	7,400	966	$1,978.01
5	Gas	Cond Basement	Frame	2021	Ventilation option	8,927	960	$2,170.36
5	Gas	Cond Crawl	Frame	2021	Ventilation option	7,482	901	$1,920.36
5	Gas	Slab	Frame	2021	Duct option	7,022	929	$1,889.94
6	Gas	Slab	Frame	2018	Base	7,374	1,201	$2,221.61
6	Gas	Cond Basement	Frame	2018	Base	8,962	1,166	$2,391.42
6	Gas	Cond Crawl	Frame	2018	Base	7,345	1,057	$2,066.49
6	Gas	Slab	Frame	2018	2021 ceiling insulation	7,359	1,192	$2,210.20
6	Gas	Cond Basement	Frame	2018	2021 ceiling insulation	8,945	1,155	$2,377.65
6	Gas	Cond Crawl	Frame	2018	2021 ceiling insulation	7,333	1,047	$2,054.42

6	Gas	Slab	Frame	2021	Base	6,970	1,198	$2,165.90
6	Gas	Cond Basement	Frame	2021	Base	8,379	1,162	$2,311.37
6	Gas	Cond Crawl	Frame	2021	Base	6,937	1,052	$2,008.16
6	Gas	Slab	Frame	2021	HVAC option	6,586	1,054	$1,964.59
6	Gas	Cond Basement	Frame	2021	HVAC option	7,984	1,024	$2,114.94
6	Gas	Cond Crawl	Frame	2021	HVAC option	6,583	930	$1,833.88
6	Gas	Slab	Frame	2021	Water Heater option	7,007	1,183	$2,155.00
6	Gas	Cond Basement	Frame	2021	Water Heater option	8,408	1,131	$2,282.00
6	Gas	Cond Crawl	Frame	2021	Water Heater option	6,973	1,033	$1,993.00
6	Gas	Slab	Frame	2021	Ventilation option	7,198	1,126	$2,119.89
6	Gas	Cond Basement	Frame	2021	Ventilation option	8,672	1,068	$2,250.70
6	Gas	Cond Crawl	Frame	2021	Ventilation option	7,189	995	$1,981.03
6	Gas	Slab	Frame	2021	Duct option	6,832	1,043	$1,985.04
7	Gas	Slab	Frame	2018	Base	7,284	1,701	**$2,735.00**
7	Gas	Cond Basement	Frame	2018	Base	8,822	1,641	$2,873.00
7	Gas	Cond Crawl	Frame	2018	Base	7,236	1,497	$2,515.00
7	Gas	Slab	Frame	2018	2021 ceiling insulation	7,239	1,694	$2,722.00
7	Gas	Cond Basement	Frame	2018	2021 ceiling insulation	8,807	1,628	$2,857.00
7	Gas	Cond Crawl	Frame	2018	2021 ceiling insulation	7,221	1,484	$2,499.00
7	Gas	Slab	Frame	2021	Base	7,321	1,605	$2,639.32
7	Gas	Cond Basement	Frame	2021	Base	8,787	1,523	$2,743.86
7	Gas	Cond Crawl	Frame	2021	Base	7,283	1,419	$2,438.89
7	Gas	Slab	Frame	2021	HVAC option	6,879	1,403	$2,369.51
7	Gas	Cond Basement	Frame	2021	HVAC option	8,344	1,333	$2,486.54

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7	Gas	Cond Crawl	Frame	2021	HVAC option	6,870	1,244	$2,201.23
7	Gas	Slab	Frame	2021	Water Heater option	7,374	1,594	$2,635.00
7	Gas	Cond Basement	Frame	2021	Water Heater option	8,824	1,494	$2,718.00
7	Gas	Cond Crawl	Frame	2021	Water Heater option	7,327	1,404	$2,429.00
7	Gas	Slab	Frame	2021	Ventilation option	7,307	1,588	$2,619.63
7	Gas	Cond Basement	Frame	2021	Ventilation option	8,772	1,502	$2,719.84
7	Gas	Cond Crawl	Frame	2021	Ventilation option	7,271	1,403	$2,420.51
7	Gas	Slab	Frame	2021	Duct option	7,210	1,409	$2,418.88
7	Gas	Slab	Frame	2021	No HRV	7,087	1,671	$2,678.24
7	Gas	Cond Basement	Frame	2021	No HRV	8,479	1,607	$2,792.07
7	Gas	Cond Crawl	Frame	2021	No HRV	7,028	1,466	$2,455.11

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Acronyms and Abbreviations

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

1.0 Highlights

Moving to the ASHRAE Standard 90.1-2019 (ASHRAE 2019) edition from Standard 90.1-2016 (ASHRAE 2016) is cost-effective for Michigan. Standard 90.1-2019 will provide an annual energy cost savings of $0.063 per square foot on average across the state. It will reduce statewide CO_2 emissions by 10.0 MMT (30 years cumulative), equivalent to the CO_2 emissions of 2,182,000 cars driven for one year.

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

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

Consumer Impact	
Annual (first year) energy cost savings, $/ft²	$0.063
Added construction cost, $/ft²	-$1.198
Publicly-owned scenario LCC Savings, $/ft²	4.22
Privately-owned scenario LCC Savings, $/ft²	3.70

Statewide Impact - Emissions	**First Year**	**30 Years Cumulative**
Energy cost savings, 2020$	1,587,000	683,500,000
CO_2 emission reduction, Metric tons	14,390	10,030,000
CH_4 emissions reductions, Metric tons	1.30	906
N_2O emissions reductions, Metric tons	0.185	129
NOx emissions reductions, Metric tons	9.96	6,946
SOx emissions reductions, Metric tons	11.81	8,232

Statewide Impact - Jobs Created	**First Year**	**30 Years Cumulative**
Jobs Created Reduction in Utility Bills	127	4,008
Jobs Created Construction Related Activities	186	5,896

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

The report provides analysis of two LCC scenarios:

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

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

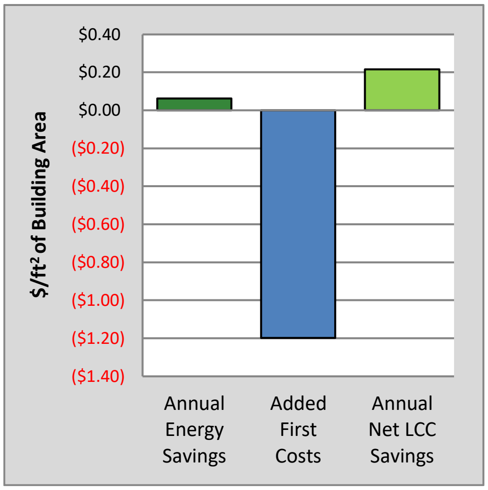

Figure 1. Statewide Weighted Costs and Savings

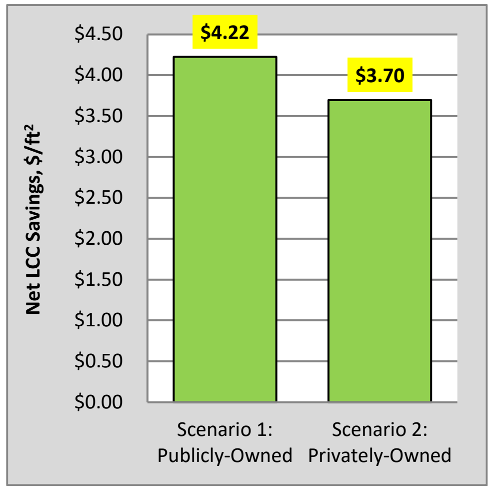

Figure 2. Overall Net Life-Cycle Cost Savings

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

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

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

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

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

Table 1 shows the present value of the net LCC savings over 30 years for buildings in scenario 1 averages $4.22 per square foot for Standard 90.1-2019.

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

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
5A	$4.00	$4.07	$4.50	$4.94	$13.52	$2.01	$4.87
6A	$3.97	$4.03	$4.20	$4.99	$13.45	$2.20	$4.18
7	$3.96	$4.02	$4.11	$5.04	$13.19	$2.80	$4.56
State Average	$3.97	$4.03	$4.19	$4.99	$13.42	$2.23	**$4.22**

Table 2 shows the present value of the net LCC savings over 30 years averages $3.70 per square foot for scenario 2.

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

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
5A	$3.36	$3.35	$3.89	$4.17	$13.05	$1.81	$4.35
6A	$3.34	$3.33	$3.63	$4.21	$12.99	$1.98	$3.65
7	$3.34	$3.31	$3.54	$4.26	$12.76	$2.51	$4.00
State Average	$3.34	$3.33	$3.62	$4.21	$12.96	$2.00	**$3.70**

2.1 Energy Cost Savings

Table 3 shows the economic impact of upgrading to Standard 90.1-2019 by building type and climate zone in terms of the annual energy cost savings in dollars per square foot. The annual energy cost savings across the state averages $0.063 per square foot.

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

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
5A	$0.048	$0.058	$0.096	$0.072	$0.082	$0.019	$0.073
6A	$0.048	$0.057	$0.082	$0.073	$0.079	$0.021	$0.062
7	$0.052	$0.057	$0.074	$0.072	$0.066	$0.030	$0.067
State Average	$0.048	$0.057	$0.081	$0.073	$0.077	$0.021	**$0.063**

2.2 Construction Weighting of Results

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

Table 4. Construction Weights by Building Type

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
5A	0.1%	0.0%	0.5%	0.0%	0.1%	0.2%	1.0%
6A	11.5%	3.6%	40.7%	9.4%	3.6%	19.7%	88.5%
7	1.2%	0.0%	6.9%	0.9%	0.6%	1.0%	10.6%
State Average	12.8%	3.6%	48.1%	10.3%	4.3%	20.9%	100.0%

2.3 Incremental Construction Cost

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

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

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

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

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

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
5A	($1.748)	($2.029)	($1.363)	($2.042)	$0.666	($0.381)	($1.013)
6A	($1.728)	($2.008)	($1.305)	($2.053)	$0.675	($0.444)	($1.196)
7	($1.667)	($1.992)	($1.299)	($2.055)	$0.714	($0.612)	($1.227)
State Average	($1.722)	($2.008)	($1.305)	($2.053)	$0.680	($0.452)	**($1.198)**

2.4 Simple Payback

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

Table 6. Simple Payback for Michigan (Years)

Climate Zone	Small Office	Large Office	Stand-Alone Retail	Primary School	Small Hotel	Mid-Rise Apartment	All Building Types
5A	Immediate	Immediate	Immediate	Immediate	8.2	Immediate	Immediate
6A	Immediate	Immediate	Immediate	Immediate	8.6	Immediate	Immediate
7	Immediate	Immediate	Immediate	Immediate	10.8	Immediate	Immediate
State Average	Immediate	Immediate	Immediate	Immediate	8.8	Immediate	**Immediate**

3.0 Societal Benefits

3.1 Benefits of Energy Codes

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

3.2 Greenhouse Gas Emissions

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

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

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

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

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

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

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

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

Table 7. Greenhouse Gas Emission Factors by Fuel Type

GHG	Electricity lb/MWh	Natural Gas (lb/mmcf)
CO_2	1,839	120,000
SO_2	1.610	0.6
NO_X	1.259	96
N_2O	0.025	0.23
CH_4	0.175	2.3

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

Table 8. Societal Benefits of Standard 90.1-2019

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, 2020$	1,587,000	683,500,000
CO_2 emission reduction, Metric tons	14,390	10,030,000
CH_4 emissions reductions, Metric tons	1.30	906
N_2O emissions reductions, Metric tons	0.185	129
NOx emissions reductions, Metric tons	9.96	6,946
SOx emissions reductions, Metric tons	11.81	8,232

3.3 Jobs Creation through Energy Efficiency

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

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

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

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

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

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

Table 9. Jobs Created from Standard 90.1-2019

Statewide Impact	First Year	30 Years Cumulative
Jobs Created Reduction in Utility Bills	127	4,008
Jobs Created Construction Related Activities	186	5,896

4.0 Overview of the Cost-Effectiveness Methodology

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

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

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

4.1 Cost-Effectiveness

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

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

Two cost scenarios are analyzed:

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

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

4.2 Building Prototypes and Energy Modeling

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

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

Table 10. Building Prototypes

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

4.3 Climate Zones

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

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

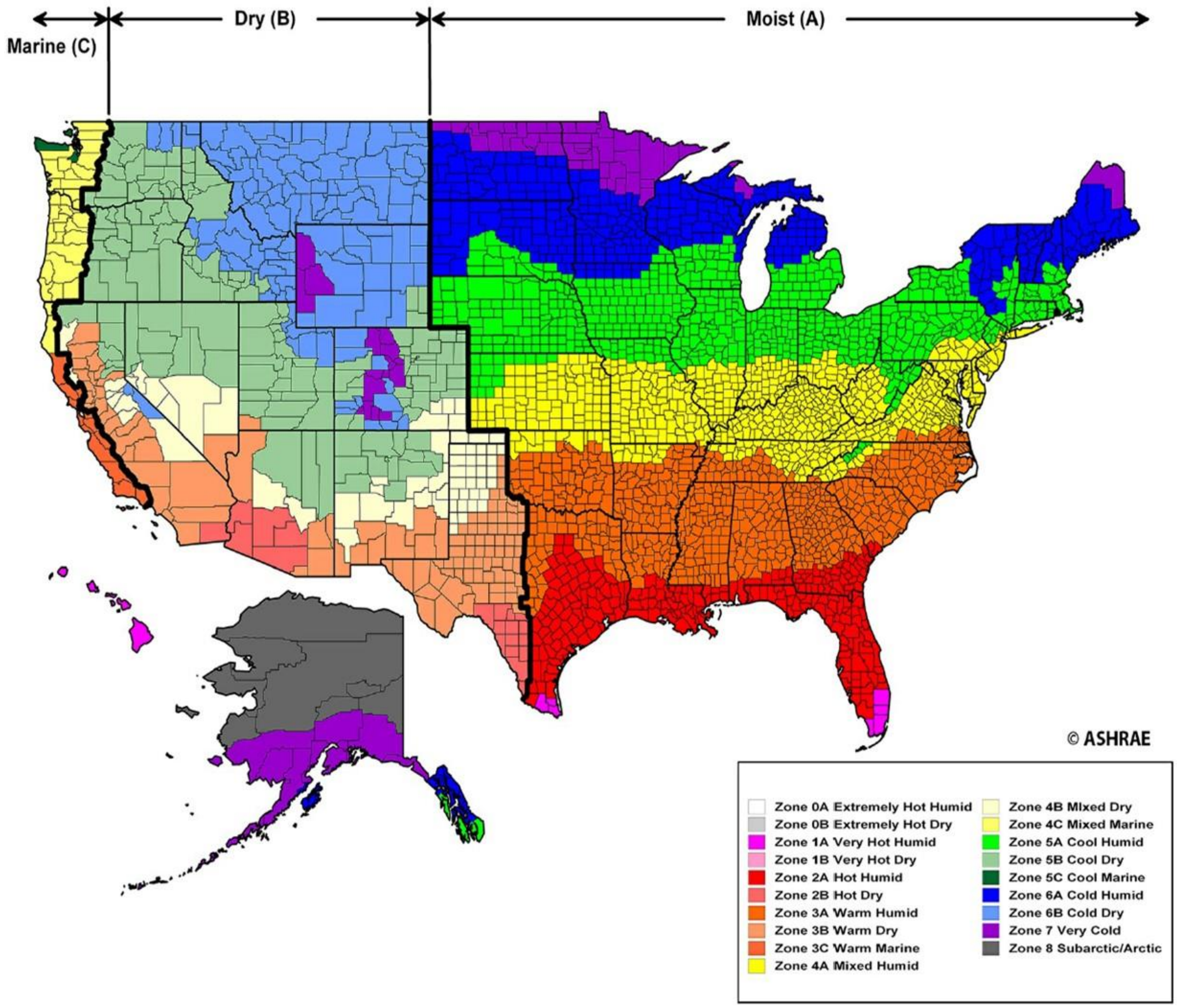

Figure 3. National Climate Zones

4.4 Cost-Effectiveness Method and Parameters

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

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

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

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

Table 11. LCC Economic Parameters

Economic Parameter	Scenario 1	Scenario 2
Study Period – Years[1]	30	30
Nominal Discount Rate[2]	3.10%	5.25%
Real Discount Rate[2]	3.00%	3.34%
Effective Inflation Rate[3]	0.10%	1.85%
Electricity Prices[4] (per kWh)	$0.1177	$0.1177
Natural Gas Prices[4] (per therm)	$0.6612	$0.6612
Energy Price Escalation Factors[5]	*Uniform present value factors*	*Uniform present value factors*
Electricity Price UPV[5]	19.17	17.37
Natural Gas Price UPV[5]	23.45	21.25
Loan Interest Rate[6]	NA	5.25%
Federal Corporate Tax Rate[7]	NA	21.00%
State Corporate Tax Rate[8]	NA	6.00%
Combined Income Tax Impact[9]	NA	25.74%
State and Average Local Sales Tax[10]	6.00%	6.00%
State Construction Cost Index[11]	0.964	0.964

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

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

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

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

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

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

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

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

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

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

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

5.0 Detailed Energy Use and Cost

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

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

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

Electricity	$0.1177	kWh
Gas	$0.6612	Therm

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

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

Climate Zone:	5A				6A				7			
Code:	90.1-2016	90.1-2019	Savings		90.1-2016	90.1-2019	Savings		90.1-2016	90.1-2019	Savings	
Small Office												
Electricity	$0.903	$0.855	$0.049	5.4%	$0.902	$0.852	$0.050	5.5%	$0.874	$0.820	$0.054	6.2%
Gas	$0.017	$0.017	-$0.001	-5.9%	$0.020	$0.021	-$0.002	-10.0%	$0.033	$0.035	-$0.002	-6.1%
Totals	$0.920	$0.872	$0.048	5.2%	$0.921	$0.873	$0.048	5.2%	$0.907	$0.855	$0.052	5.7%
Large Office												
Electricity	$1.751	$1.694	$0.057	3.3%	$1.725	$1.669	$0.057	3.3%	$1.700	$1.644	$0.056	3.3%
Gas	$0.028	$0.027	$0.001	3.6%	$0.027	$0.026	$0.001	3.7%	$0.027	$0.027	$0.000	0.0%
Totals	$1.779	$1.721	$0.058	3.3%	$1.752	$1.695	$0.057	3.3%	$1.727	$1.671	$0.057	3.3%
Stand-Alone Retail												
Electricity	$1.062	$0.958	$0.104	9.8%	$1.050	$0.960	$0.090	8.6%	$1.041	$0.962	$0.079	7.6%
Gas	$0.185	$0.194	-$0.009	-4.9%	$0.208	$0.217	-$0.009	-4.3%	$0.125	$0.131	-$0.006	-4.8%
Totals	$1.247	$1.152	$0.096	7.7%	$1.259	$1.177	$0.082	6.5%	$1.166	$1.092	$0.074	6.3%
Primary School												
Electricity	$1.039	$0.969	$0.070	6.7%	$1.002	$0.930	$0.072	7.2%	$0.968	$0.898	$0.070	7.2%
Gas	$0.101	$0.099	$0.002	2.0%	$0.109	$0.108	$0.001	0.9%	$0.116	$0.113	$0.003	2.6%
Totals	$1.140	$1.068	$0.072	6.3%	$1.111	$1.038	$0.073	6.6%	$1.084	$1.012	$0.072	6.6%
Small Hotel												
Electricity	$1.085	$1.004	$0.081	7.5%	$1.071	$0.993	$0.078	7.3%	$1.079	$1.013	$0.065	6.0%
Gas	$0.172	$0.171	$0.000	0.0%	$0.179	$0.178	$0.001	0.6%	$0.184	$0.183	$0.001	0.5%
Totals	$1.256	$1.175	$0.082	6.5%	$1.250	$1.171	$0.079	6.3%	$1.263	$1.196	$0.066	5.2%
Mid-Rise Apartment												
Electricity	$1.183	$1.159	$0.023	1.9%	$1.184	$1.158	$0.027	2.3%	$1.190	$1.163	$0.027	2.3%
Gas	$0.039	$0.043	-$0.004	-10.3%	$0.037	$0.042	-$0.006	-16.2%	$0.044	$0.041	$0.003	6.8%
Totals	$1.221	$1.202	$0.019	1.6%	$1.221	$1.200	$0.021	1.7%	$1.234	$1.204	$0.030	2.4%

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

Climate Zone:	5A				6A				7			
Code:	90.1-2016	90.1-2019	Savings		90.1-2016	90.1-2019	Savings		90.1-2016	90.1-2019	Savings	
Small Office												
Electricity, kWh/ft^2	7.675	7.262	0.414	5.4%	7.661	7.239	0.421	5.5%	7.424	6.963	0.461	6.2%
Gas, therm/ft^2	0.025	0.026	-0.001	-4.0%	0.030	0.032	-0.003	-10.0%	0.050	0.053	-0.003	-6.0%
Totals, kBtu/ft^2	28.695	27.402	1.293	4.5%	29.108	27.929	1.179	4.1%	30.340	29.105	1.234	4.1%
Large Office												
Electricity, kWh/ft^2	14.876	14.389	0.487	3.3%	14.659	14.177	0.482	3.3%	14.446	13.968	0.479	3.3%
Gas, therm/ft^2	0.042	0.041	0.001	2.4%	0.040	0.040	0.001	2.5%	0.041	0.040	0.000	0.0%
Totals, kBtu/ft^2	54.978	53.206	1.772	3.2%	54.075	52.345	1.730	3.2%	53.389	51.716	1.673	3.1%
Stand-Alone Retail												
Electricity, kWh/ft^2	9.027	8.140	0.886	9.8%	8.924	8.156	0.768	8.6%	8.846	8.172	0.674	7.6%
Gas, therm/ft^2	0.280	0.293	-0.013	-4.6%	0.315	0.328	-0.013	-4.1%	0.189	0.197	-0.008	-4.2%
Totals, kBtu/ft^2	58.797	57.101	1.696	2.9%	61.941	60.623	1.318	2.1%	49.101	47.634	1.467	3.0%
Primary School												
Electricity, kWh/ft^2	8.829	8.233	0.597	6.8%	8.510	7.901	0.610	7.2%	8.226	7.633	0.593	7.2%
Gas, therm/ft^2	0.153	0.150	0.003	2.0%	0.165	0.164	0.002	1.2%	0.176	0.172	0.004	2.3%
Totals, kBtu/ft^2	45.432	43.084	2.348	5.2%	45.587	43.329	2.258	5.0%	45.649	43.215	2.433	5.3%
Small Hotel												
Electricity, kWh/ft^2	9.217	8.528	0.689	7.5%	9.096	8.434	0.662	7.3%	9.164	8.610	0.554	6.0%
Gas, therm/ft^2	0.260	0.259	0.001	0.4%	0.271	0.270	0.001	0.4%	0.279	0.277	0.002	0.7%
Totals, kBtu/ft^2	57.411	54.988	2.422	4.2%	58.135	55.778	2.357	4.1%	59.148	57.066	2.082	3.5%
Mid-Rise Apartment												
Electricity, kWh/ft^2	10.047	9.850	0.197	2.0%	10.062	9.837	0.226	2.2%	10.113	9.881	0.231	2.3%
Gas, therm/ft^2	0.059	0.065	-0.006	-10.2%	0.055	0.064	-0.008	-14.5%	0.067	0.062	0.005	7.5%
Totals, kBtu/ft^2	40.152	40.089	0.063	0.2%	39.871	39.941	-0.070	-0.2%	41.204	39.962	1.242	3.0%

Table 15.A. Annual Energy Usage for Buildings in Michigan in Climate Zone 7

Energy End-Use	Small Office		Large Office		Stand-Alone Retail		Primary School		Small Hotel		Mid-Rise Apartment	
	Electric kWh/ $ft^2 \cdot yr$	Gas therms/ $ft^2 \cdot yr$	Electric kWh/ $ft^2 \cdot yr$	Gas therms/ $ft^2 \cdot yr$	Electric kWh/ $ft^2 \cdot yr$	Gas therms/ $ft^2 \cdot yr$	Electric kWh/ $ft^2 \cdot yr$	Gas therms/ $ft^2 \cdot yr$	Electric kWh/ $ft^2 \cdot yr$	Gas therms/ $ft^2 \cdot yr$	Electric kWh/ $ft^2 \cdot yr$	Gas therms/ $ft^2 \cdot yr$
ASHRAE 90.1-2016												
Heating, Humidification	0.972	0.050	0.886	0.028	0.000	0.151	0.000	0.112	1.288	0.031	0.000	0.067
Cooling	0.344	0.000	0.952	0.000	0.677	0.000	0.621	0.000	1.034	0.000	0.485	0.000
Fans, Pumps, Heat Recovery	0.873	0.000	1.380	0.000	1.928	0.000	1.524	0.000	1.143	0.000	0.591	0.000
Lighting, Interior & Exterior	1.887	0.000	1.960	0.000	4.055	0.000	1.382	0.000	2.112	0.000	1.054	0.000
Plugs, Refrigeration, Other	2.439	0.000	9.269	0.000	2.186	0.000	4.602	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.013	0.000	0.038	0.097	0.018	0.000	0.155	3.774	0.000
Total	7.424	0.050	14.446	0.041	8.846	0.189	8.226	0.176	9.164	0.279	10.113	0.067
ASHRAE 90.1-2019												
Heating, Humidification	0.975	0.053	0.885	0.028	0.000	0.159	0.000	0.108	1.421	0.029	0.000	0.062
Cooling	0.292	0.000	0.866	0.000	0.589	0.000	0.562	0.000	0.927	0.000	0.447	0.000
Fans, Pumps, Heat Recovery	0.761	0.000	1.314	0.000	1.968	0.000	1.366	0.000	1.215	0.000	0.551	0.000
Lighting, Interior & Exterior	1.587	0.000	1.633	0.000	3.429	0.000	1.151	0.000	1.461	0.000	0.900	0.000
Plugs, Refrigeration, Other	2.439	0.000	9.269	0.000	2.187	0.000	4.458	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.013	0.000	0.038	0.097	0.018	0.000	0.155	3.774	0.000
Total	6.963	0.053	13.968	0.040	8.172	0.197	7.633	0.172	8.610	0.277	9.881	0.062
Total Savings	0.461	-0.003	0.479	0.000	0.674	-0.008	0.593	0.004	0.554	0.002	0.231	0.005

Table 15.B. Annual Energy Usage for Buildings in Michigan in Climate Zone 5A

Energy End-Use	Small Office		Large Office		Stand-Alone Retail		Primary School		Small Hotel		Mid-Rise Apartment	
	Electric kWh/ ft^2·yr	Gas therms/ ft^2·yr	Electric kWh/ ft^2·yr	Gas therms/ ft^2·yr	Electric kWh/ ft^2·yr	Gas therms/ ft^2·yr	Electric kWh/ ft^2·yr	Gas therms/ ft^2·yr	Electric kWh/ ft^2·yr	Gas therms/ ft^2·yr	Electric kWh/ ft^2·yr	Gas therms/ ft^2·yr
ASHRAE 90.1-2016												
Heating, Humidification	0.953	0.025	0.779	0.030	0.000	0.243	0.000	0.090	1.080	0.024	0.000	0.059
Cooling	0.592	0.000	1.491	0.000	1.205	0.000	1.181	0.000	1.377	0.000	0.664	0.000
Fans, Pumps, Heat Recovery	0.886	0.000	1.377	0.000	1.799	0.000	1.549	0.000	1.055	0.000	0.616	0.000
Lighting, Interior & Exterior	1.896	0.000	1.961	0.000	3.835	0.000	1.400	0.000	2.118	0.000	1.054	0.000
Plugs, Refrigeration, Other	2.439	0.000	9.269	0.000	2.187	0.000	4.602	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.012	0.000	0.037	0.097	0.017	0.000	0.143	3.505	0.000
Total	7.675		14.876	0.042	9.027	0.280	8.829	0.153	9.217	0.260	10.047	0.059
ASHRAE 90.1-2019												
Heating, Humidification	0.959		0.778	0.029	0.000	0.256	0.000	0.087	1.201	0.023	0.000	0.065
Cooling	0.558	0.000	1.383	0.000	1.119	0.000	1.116	0.000	1.281	0.000	0.635	0.000
Fans, Pumps, Heat Recovery	0.813	0.000	1.327	0.000	1.713	0.000	1.408	0.000	0.999	0.000	0.601	0.000
Lighting, Interior & Exterior	1.584	0.000	1.632	0.000	3.122	0.000	1.154	0.000	1.461	0.000	0.900	0.000
Plugs, Refrigeration, Other	2.439	0.000	9.269	0.000	2.186	0.000	4.458	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.012	0.000	0.037	0.097	0.017	0.000	0.143	3.506	0.000
Total	7.262		14.389	0.041	8.140	0.293	8.233	0.150	8.528	0.259	9.850	0.065
Total Savings	0.414	-0.001	0.487	0.001	0.886	-0.013	0.597	0.003	0.689	0.001	0.197	-0.006

Table 15.C. Annual Energy Usage for Buildings in Michigan in Climate Zone 6A

Energy End-Use	Small Office		Large Office		Stand-Alone Retail		Primary School		Small Hotel		Mid-Rise Apartment	
	Electric kWh/ ft^2·yr	Gas therms/ ft^2·yr	Electric kWh/ ft^2·yr	Gas therms/ ft^2·yr	Electric kWh/ ft^2·yr	Gas therms/ ft^2·yr	Electric kWh/ ft^2·yr	Gas therms/ ft^2·yr	Electric kWh/ ft^2·yr	Gas therms/ ft^2·yr	Electric kWh/ ft^2·yr	Gas therms/ ft^2·yr
ASHRAE 90.1-2016												
Heating, Humidification	1.102	0.030	0.880	0.028	0.000	0.277	0.000	0.102	1.193	0.029	0.000	0.055
Cooling	0.433	0.000	1.197	0.000	0.828	0.000	0.841	0.000	1.152	0.000	0.554	0.000
Fans, Pumps, Heat Recovery	0.882	0.000	1.352	0.000	1.803	0.000	1.572	0.000	1.047	0.000	0.594	0.000
Lighting, Interior & Exterior	1.894	0.000	1.961	0.000	4.107	0.000	1.399	0.000	2.117	0.000	1.054	0.000
Plugs, Refrigeration, Other	2.438	0.000	9.269	0.000	2.186	0.000	4.602	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.012	0.000	0.038	0.097	0.017	0.000	0.150	3.651	0.000
Total	7.661	0.030	14.659	0.040	8.924	0.315	8.510	0.165	9.096	0.271	10.062	0.055
ASHRAE 90.1-2019												
Heating, Humidification	1.115	0.032	0.880	0.027	0.000	0.290	0.000	0.100	1.337	0.028	0.000	0.064
Cooling	0.392	0.000	1.100	0.000	0.770	0.000	0.779	0.000	1.059	0.000	0.503	0.000
Fans, Pumps, Heat Recovery	0.797	0.000	1.297	0.000	1.727	0.000	1.408	0.000	0.990	0.000	0.573	0.000
Lighting, Interior & Exterior	1.587	0.000	1.633	0.000	3.473	0.000	1.158	0.000	1.462	0.000	0.900	0.000
Plugs, Refrigeration, Other	2.439	0.000	9.269	0.000	2.187	0.000	4.458	0.046	3.587	0.092	4.209	0.000
Service Water Heating (SWH)	0.910	0.000	0.000	0.012	0.000	0.038	0.097	0.017	0.000	0.150	3.652	0.000
Total	7.239	0.032	14.177	0.040	8.156	0.328	7.901	0.164	8.434	0.270	9.837	0.064
Total Savings	0.421	-0.003	0.482	0.001	0.768	-0.013	0.610	0.002	0.662	0.001	0.226	-0.008

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U.S. DEPARTMENT OF ENERGY

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Highlights

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

Moving to the 2021 International Energy Conservation Code (IECC) is cost-effective for both single-family and low-rise multifamily residential buildings in Michigan. The 2021 IECC will provide statewide energy savings of 10.7% across all climate zones compared to the current state energy code. This equates to $ 327 of annual utility bill savings for the average Michigan household. It will reduce statewide CO_2 emissions over 30 years by 11,460,000 metric tons, equivalent to the annual CO_2 emissions of 2,493,000 cars on the road (1 MMT CO_2 = 217,480 cars driven/year). Updating the state energy code based on the 2021 IECC will also stimulate the creation of high-quality jobs across the state. Adopting the 2021 IECC in Michigan is expected to result in homes that are energy efficient, more affordable to own and operate, and based on current industry standards for health, comfort and resilience.

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

Consumer Impact

Metric	Compared to the 2015 IECC with amendments
Life-cycle cost savings of the 2021 IECC	$4,514
Net annual consumer cash flow in year 1 of the 2021 IECC[2]	$97
Annual (first year) energy cost savings of the 2021 IECC ($)[3]	$327
Annual (first year) energy cost savings of the 2021 IECC (%)[4]	10.7%

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

Statewide Impact - Emissions

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, $	3,873,000	1,251,000,000
CO_2 emission reduction, Metric tons	24,960	11,460,000
CH_4 emissions reductions, Metric tons	1.83	839
N_2O emissions reductions, Metric tons	0.255	117
NOx emissions reductions, Metric tons	17.93	8,231
SOx emissions reductions, Metric tons	15.57	7,151

Statewide Impact – Jobs Created

Statewide Impact	First Year	30 Years Cumulative
Jobs Created -- Reduction in Utility Bills	187	4,851
Jobs Created -- Construction Related Activities	257	6,675

Acronyms and Abbreviations

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

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1.0 Cost-Effectiveness Results for the 2021 IECC for Michigan

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

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

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

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

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

1.1 Life-Cycle Cost

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

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

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

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

Climate Zone	Life-Cycle Cost Savings ($)
5A	4,480
6A	4,670
7	6,470
State Average	**4,514**

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

1.2 Consumer Cash Flow

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

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

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

	Cost/Benefit	5A	6A	7	State Average
A	Incremental down payment and other first costs	$506	$433	$624	$499
B	Annual energy savings (year one)	$338	$324	$476	$337
C	Annual mortgage increase	$175	$150	$216	$172
D	Net annual cost of mortgage interest deductions, mortgage insurance, and property taxes (year one)	$69	$59	$85	$68
E = [B-(C+D)]	Net annual cash flow savings (year one)	$94	$116	$175	$97
F = [A/E]	Years to positive savings, including up-front cost impacts	5	4	4	5

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

1.3 Simple Payback Period

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

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

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

Climate Zone	Payback Period (Years)
5A	12.0
6A	10.7
7	10.5
State Average	**11.8**

2.0 Overview of the Cost-Effectiveness Analysis Methodology

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

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

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

2.1 Estimation of Energy Usage and Savings

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

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

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

2.2 Climate Zones

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

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

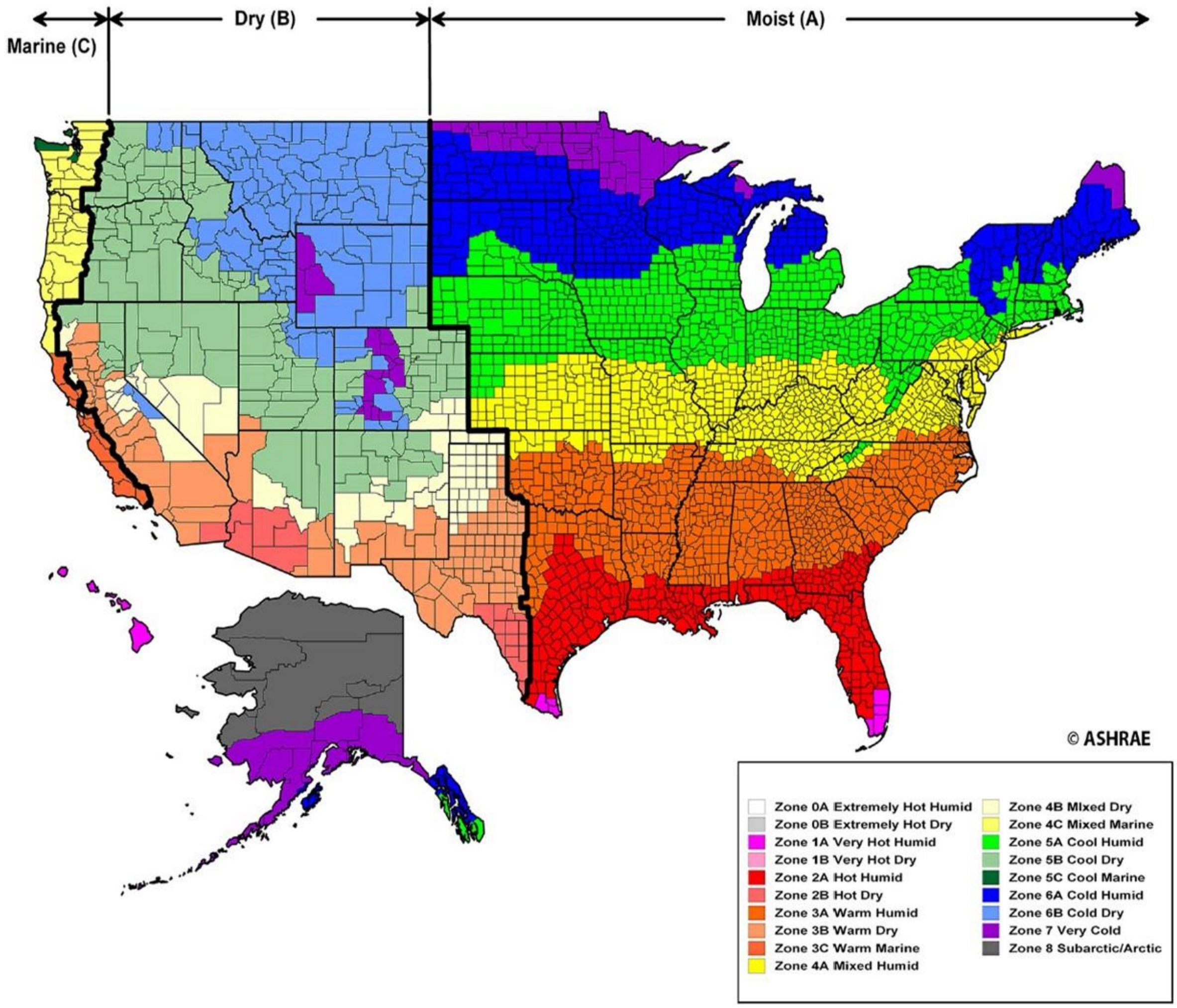

Figure 1. National Climate Zones

2.3 Fuel Prices

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

Table 4. Fuel Prices used in the Analysis

Electricity ($/kWh)	Gas ($/Therm)	Oil ($/MBtu)
0.164	0.721	2.279

2.4 Financial and Economic Parameters

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

Table 5. Economic Parameters Used in the Analysis

Parameter	Value
Mortgage interest rate (fixed rate)	3%
Loan fees	1% of mortgage amount
Loan term	30 years
Down payment	12% of home value
Nominal discount rate (equal to mortgage rate)	3%
Inflation rate	1.4%
Marginal federal income tax	12%
Marginal state income tax	4.25%
Property tax	1.62%

2.5 Aggregation Scheme

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

Table 6. Heating Equipment Shares

Heating System	Share of New Homes (percent)	
	Single-Family	Multifamily
Natural Gas	78.4	78.4
Heat Pump	20.5	20.5
Electric Resistance	0.6	0.6
Oil	0.5	0.5

Table 7. Foundation Type Shares

Foundation Type	Slab-on-grade	Heated Basement	Unheated Basement	Crawlspace
Share of New Homes (percent)	15.4	35.9	28.2	20.5

Table 8. Construction Shares by Climate Zone

Climate Zone	Share of New Homes (percent)	
	Single-Family	Multifamily
5A	81.5	18.5
6A	81.5	18.5
7	81.5	18.5

3.0 Incremental Construction Costs

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

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

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

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

Table 9 and Table 10 show the incremental construction costs associated with the 2021 IECC compared to the 2015 IECC with amendments for an individual dwelling unit. Table 9 shows results for a house and Table 10 shows results for an apartment or condominium. These have been adjusted using a construction cost multiplier, 0.989, to reflect local construction costs based on location factors provided by RSMeans (2020).

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

Single-family Prototype House				
Climate Zone	**Crawlspace**	**Heated Basement**	**Slab**	**Unheated Basement**
5A	$4,116	$4,787	$4,624	$4,116
6A	$3,780	$3,780	$3,780	$3,780
7	$5,264	$5,264	$5,264	$5,264

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

Multifamily Prototype Apartment/Condo				
Climate Zone	**Crawlspace**	**Heated Basement**	**Slab**	**Unheated Basement**
5A	$1,645	$1,744	$1,720	$1,645
6A	$1,523	$1,523	$1,523	$1,523
7	$3,006	$3,006	$3,006	$3,006

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

4.0 Energy Cost Savings

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

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

Climate Zone	2015 IECC with amendments						
	Heating	**Cooling**	**Water Heating**	**Lighting**	**Fans**	**Vents**	**Total**
5A	$894	$229	$220	$252	$183	$59	$3,055
6A	$1,007	$166	$233	$252	$177	$59	$3,112
7	$1,163	$118	$244	$252	$161	$59	$3,215
State Average	**$908**	**$222**	**$221**	**$252**	**$182**	**$59**	**$3,062**

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

Climate Zone	2021 IECC						
	Heating	**Cooling**	**Water Heating**	**Lighting**	**Fans**	**Vents**	**Total**
5A	$793	$201	$105	$220	$161	$29	$2,727
6A	$915	$144	$113	$220	$158	$29	$2,797
7	$882	$115	$120	$220	$131	$69	$2,753
State Average	**$806**	**$194**	**$106**	**$220**	**$160**	**$30**	**$2,735**

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

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

Climate Zone	First Year Energy Cost Savings	First Year Energy Cost Savings (percent)
5A	$328	10.7%
6A	$315	10.1%
7	$462	14.4%
State Average	**$327**	**10.7%**

5.0 Societal Benefits

5.1 Benefits of Energy Codes

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

5.2 Greenhouse Gas Emissions

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

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

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

[1] Architecture 2030

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

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

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

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

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

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

GHG	Electricity lb/MWh	Natural Gas (lb/mmcf)	Fuel Oil (lb/1000 gal)
CO_2	1,839	120,000	23,000
SO_2	1.610	0.6	12
NO_X	1.261	96	19
N_2O	0.032	0.23	0.45
CH_4	0.183	2.3	0.7

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

Table 15. Societal Benefits of the 2021 IECC

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, $	3,873,000	1,251,000,000
CO_2 emission reduction, Metric tons	24,960	11,460,000
CH_4 emissions reductions, Metric tons	1.83	839
N_2O emissions reductions, Metric tons	0.255	117
NOx emissions reductions, Metric tons	17.93	8,231
SOx emissions reductions, Metric tons	15.57	7,151

5.3 Jobs Creation through Energy Efficiency

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

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

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

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

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

Table 16. Jobs Created from the 2021 IECC

Statewide Impact	First Year	30 Years Cumulative
Jobs Created -- Reduction in Utility Bills	187	4,851
Jobs Created -- Construction Related Activities	257	6,675

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RECA
Responsible Energy Codes Alliance

Submitted via Email

July 5, 2022

Keith Lambert, Director
Bureau of Construction Codes
Michigan Department of Licensing and Regulatory Affairs
Administrative Services Division
P.O. Box 30254
Lansing, MI 48909

RE: Pending Rule Set #2021-48 LR and #2021-49 LR, Additional Comments of the Responsible Energy Codes Alliance (RECA) Supporting the Adoption of the 2021 *IECC* as the Michigan Construction Code Parts 10 and 10a

Dear Director Lambert,

As we noted in our July 16, 2021 and March 16, 2022 letters to the Bureau of Construction Codes, RECA supports Michigan's proposed adoption of the 2021 IECC for residential construction and the 2021 IECC/ASHRAE Standard 90.1-2019 for commercial construction, and we continue to support the rule as published in the July 1, 2022 Michigan Register. Although we believe the record contains ample support for the Department's proposed action, in the interest of providing a more complete record, we are submitting complete copies of the U.S. Department of Energy's analyses of these two model codes demonstrating clear cost-effectiveness and a range of other benefits for residential and commercial building owners in Michigan. In addition, we are submitting copies of an additional cost-effectiveness analysis completed by ICF International that confirms and extends the findings of the U.S. DOE analysis of the 2021 IECC, and directly rebuts the analysis prepared by the National Association of Homebuilders.

Given the overwhelming support for the adoption of the model energy codes and the broad range of economic and environmental benefits outlined in RECA's and other stakeholders' previous comments, we encourage the Bureau to move quickly to finalize and implement the proposed Rule. Please contact us if you have any questions or would like to discuss how RECA can be of assistance.

Sincerely,

Eric Lacey
RECA Chairman

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
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July 5, 2022

Dear Director Hawks, Deputy Director Pendleton, and Director Lambert:

Thank you for the opportunity to comment regarding the proposed rule sets (2021 – 48 LR & 2021 – 49 LR) to amend the Michigan Energy Code. The Michigan Energy Innovation Business Council (Michigan EIBC) is a business trade association representing over 140 companies across a full range of advanced energy industries, including energy efficiency, electric vehicles (EVs), renewables, demand response technologies, energy storage, and others. Michigan EIBC's mission is to grow Michigan's advanced energy economy by fostering opportunities for innovation and business growth for the advanced energy industry in the state.

Overall Comments

Updating our building codes is one of the greatest tools the State of Michigan holds to make necessary advancements in energy efficiency and advanced mobility. Michigan EIBC strongly supports the Michigan Department of Licensing and Regulatory Affairs (LARA)'s Bureau of Construction Codes (BCC)'s decision to include significant and necessary energy efficiency improvements in the residential and commercial energy code drafts. The 2021 residential edition of the International Energy Conservation Code (IECC) represents approximately a 12% improvement in efficiency through more efficient thermal envelopes, improved mechanical system efficiency, improved lighting, and other cost-effective improvements compared to the 2015 model code, which is similar to Michigan's current code. Implementing the residential IECC will save Michigan residents money on their energy bills, continue to support the growing industry in energy efficiency, and advance the work in futureproofing Michigan's building stock.

Michigan EIBC strongly urges LARA to push further to ensure Michigan continues on this track. Specifically, Michigan EIBC recommends including amendments to require EV charging readiness in both the residential and commercial codes. And in the commercial code, we strongly urge LARA to add the energy monitoring requirements from the 2021 IECC back into the final Michigan code. These additions will ensure new homes and buildings are equipped to charge their cars and ensure new businesses and multifamily homes are properly monitored through energy monitoring, so they can be better maintained over the long-term.

EV Readiness: Residential and Commercial Codes

Michigan EIBC strongly urges the BCC to include language requiring that all new homes are EV ready and commercial buildings/multi-family housing with parking include EV ready spaces. Both of these recommendations were included in the MI Healthy Climate Plan and the Michigan Council on Future Mobility & Electrification's 2021 Report.[1, 2] Additionally, cities in Michigan are already moving in this direction: Ann Arbor adopted an EV charging and readiness ordinance for new developments last year, and Lansing is currently considering a similar ordinance.[3, 4] These additions will not only support Michigan's advanced mobility future and economy, but also, they will save residential customers and commercial building owners money and they will help to protect public health.

Due to improved technology and increased consumer demand, the transition to EVs is well underway, and Michigan's future buildings should be ready for this shift. Auto manufacturers are embracing the transition to EVs. For example, both General

[1] Michigan Department of Environment, Great Lakes, and Energy. "MI Healthy Climate Plan." April, 2022. Available at https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Offices/OCE/MI-Healthy-Climate-Plan.pdf?rev=d13f4adc2b1d45909bd708cafccbfffa&hash=99437BF2709B9B3471D16FC1EC692588.

[2] Michigan Department of Labor and Economic Opportunity. "Council on Future Mobility and Electrification 2021 Report." Available at https://www.michigan.gov/documents/leo/CFME_Report_2021_738091_7.pdf.

[3] Stanton, Ryan. MLive. "Ann Arbor council Oks ordinance requiring EV parking for new developments." January 19, 2021. Available at https://www.mlive.com/news/ann-arbor/2021/01/ann-arbor-council-oks-ordinance-requiring-ev-parking-for-new-developments.html#:~:text=For%20multi%2Dfamily%20housing%20developments,and%2065%25%20EV%2Dcapable.

[4] Wiewgorra, Luisa. Fox 47 News. "Lansing could adopt requirements for EV charging stations." Available at https://www.fox47news.com/neighborhoods/downtown-old-town-reo-town/lansing-could-adopt-requirement-for-ev-charging-stations

Motors and Ford made announcements in the past year regarding their plans to switch their manufacturing to EVs.[5, 6] Across the U.S., EV sales increased by 80 percent from 2017 to 2018, and the number of EVs on U.S. roads is projected to grow from 1 million vehicles at the end of 2018 to 18.7 million by 2030. To charge these new EVs, the U.S. will need 9.6 million charging ports -- a substantial portion of which will be installed where they are most useful for consumers: at homes and businesses.

Unfortunately, it can be costly and challenging to install charging stations at existing residential and commercial structures due to the potential need for extensive electrical upgrades. This often requires the installation of conduit through existing concrete or drywall to connect the electric vehicle supply equipment (EVSE) to electrical service. According to research from the New Buildings Institute, making homes EV ready at the time of construction can save customers $1,000 to $2,500 in retrofit costs, if they choose to install a charger at a later time. For commercial buildings and multi-family residences, EV ready construction can save about $7,000 to $8,000 in retrofit costs according to a study conducted by the California Air Resources Board.[7] Therefore, it is more cost-effective to ensure a new home or commercial building is EV ready when it is being built or undergoing major renovations than to conduct these extensive electrical upgrades when a charger is later installed.

More accessible EV charging infrastructure is also necessary to reduce carbon emissions and local air pollution. In 2018, the transportation sector was the second largest source of Michigan's greenhouse gas emissions, representing 28 percent of total emissions.[8] In order to meet Governor Whitmer's goal under Executive Directive 2020-10 of 100 percent carbon neutrality in Michigan by 2050, policies must be put in place to reduce transportation sector greenhouse gas emissions and to support the transition from gas-powered vehicles to EVs in the state.

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[5] Eisenstein, Paul A. "GM to go all-electric by 2035, phase out gas and diesel engines." Available at https://www.nbcnews.com/business/autos/gm-go-all-electric-2035-phase-out-gas-diesel-engines-n1256055.

[6] Wayland, Michael. "Ford ups EV investments, targets 40% electric car sales by 2030 under latest turnaround plan." Available at https://www.cnbc.com/2021/05/26/ford-ups-ev-investments-targets-40percent-electric-car-sales-by-2030-under-latest-turnaround-plan.html#:~:text=Ford%20Motor%20said%20Wednesday%20it,than%20%2430%20billion%20through%.

[7] California Air Resources Board. "EV Charging Infrastructure: Nonresidential Building Standards." November 15, 2019. Available at ww2.arb.ca.gov/sites/default/files/2020-08/CARB_Technical_Analysis_EV_Charging_Nonresidential_CALGreen_2019_2020_Intervening_Code.pdf.

[8] Michigan Department of Environment, Great Lakes, and Energy. "Draft MI Healthy Climate Plan." January 14, 2022. Available at https://www.michigan.gov/documents/egle/Draft-MI-Healthy-Climate-Plan_745872_7.pdf.

Additionally, according to the Health Effects Institute, "air pollution is one of the top-ranking factors for death and disability, with vehicle emissions [being] the main contributor to outdoor air pollution."[9] To both improve air quality and reduce emissions, it is necessary that Michigan prepares its future homes and businesses with the infrastructure needed to switch to EVs.

Michigan EIBC recommends the following EV readiness language be added to the residential code, including new definitions, and new Section R404.5 and revisions to Table R405.2 and Table R406.2:

Add new definitions as follows:

> **ELECTRIC VEHICLE (EV).** An automotive-type vehicle for on-road use, such as passenger automobiles, buses, trucks, vans, neighborhood electric vehicles, electric motorcycles, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, a fuel cell, a photovoltaic array, or another source of electric current. Plug-in hybrid electric vehicles are electric vehicles having a second source of motive power. Off-road, self-propelled electric mobile equipment, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats and the like, are not considered electric vehicles.
>
> **ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE).** The conductors, including the ungrounded, grounded, and equipment grounding conductors and the *electric vehicle* connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the *electric vehicle*.
>
> **LEVEL 2 ELECTRIC VEHICLE SUPPLY EQUIPMENT (Level 2 EVSE).** *Electric Vehicle Supply Equipment* capable of providing AC Level 2 EV charging.
>
> **EV READY SPACE.** A designated *parking space* that is provided with an electrical circuit capable of supporting an installed *Level 2 EVSE* in close proximity to the proposed location of the EV parking space.

Add new section as follows:

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[9] GreenBiz. "Electric bus fleets are the latest tool for improving air quality." Available at https://www.greenbiz.com/article/electric-bus-fleets-are-latest-tool-improving-air-quality.

R404.5 Electric vehicle charging infrastructure. Electric infrastructure for the current and future charging of *electric vehicles* shall be installed in accordance with this section. *EV ready spaces* are permitted to be counted toward meeting minimum parking requirements.

R404.5.1 One- and two- family dwellings and townhouses. One- and two-family dwellings and townhouses with a dedicated attached or detached garage or on-site parking spaces and new detached garages shall be provided with one *EV ready space* per *dwelling unit.* The branch circuit shall meet the following requirements:

1. A 208/240-volt circuit installations, including panel capacity, raceway wiring, receptacle, and circuit overprotection devices that are able to provide Level 2 charging
2. Terminates at a junction box or receptacle located within 3 feet (914 mm) of the parking space, and
3. The electrical panel directory shall designate the branch circuit as “For electric vehicle charging” and the junction box or receptacle shall be labelled “For electric vehicle charging”.

R404.5.2 Group R occupancies. Parking facilities serving Group R-2, R-3 and R-4 occupancies shall comply with Section C405.15.

Revise table as follows:

TABLE R405.2
REQUIREMENTS FOR TOTAL BUILDING PERFORMANCE

SECTION [a]	**TITLE**
Electrical Power and Lighting Systems	
R404.1	Lighting equipment
R404.2	Interior lighting controls
R404.5	Electric vehicle charging infrastructure

Revise table as follows:

TABLE R406.2
REQUIREMENTS FOR ENERGY RATING INDEX

SECTION [a]	**TITLE**
Electrical Power and Lighting Systems	
R404.1	Lighting equipment
R404.2	Interior lighting controls
<u>R404.5</u>	<u>Electric vehicle charging infrastructure</u>
R406.3	Building thermal envelope

Michigan EIBC recommends the following EV readiness language be added to the commercial code, including new definitions, revisions to C401.2.2 and and Table C405. 12.2, and new section C405.14:

Add new definitions as follows:

<u>**AUTOMATIC LOAD MANAGEMENT SYSTEMS (ALMS).** A control system that allows multiple connected *EVSE* to share a circuit or panel and automatically reduce power at each charger, reducing the total connected electrical capacity of all *EVSE*.</u>

<u>**ELECTRIC VEHICLE (EV).** An automotive-type vehicle for on-road use, such as passenger automobiles, buses, trucks, vans, neighborhood electric vehicles, electric motorcycles, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, a fuel cell, a photovoltaic array, or another source of electric current. Plug-in hybrid electric vehicles are electric vehicles having a second source of motive power. Off-road, self-propelled electric mobile equipment, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats and the like, are not considered electric vehicles.</u>

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE). The conductors, including the ungrounded, grounded, and equipment grounding conductors and the *electric vehicle* connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the *electric vehicle*.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) SPACE. A parking space that is provided with a dedicated *EVSE*.

EV CAPABLE SPACE. A parking space that is provided with some of the infrastructure necessary for the future installation of an *EVSE* – such as conduit, raceways, electrical capacity, or signage – or reserved physical space for such infrastructure.

EV READY SPACE. A parking space that is provided with an electrical circuit capable of supporting an installed *EVSE*.

Revise text as follows:

C401.2.2 ASHRAE 90.1
Commercial buildings shall comply with the requirements of ANSI/ASHRAE/IESNA 90.1 and Section C405.14.

Revise table as follows:

TABLE
C405.12.2 ENERGY USE CATEGORIES

LOAD CATEGORY	DESCRIPTION OF ENERGY CUSE
Total HVAC system	Heating, cooling and ventilation, including but not limited to fans, pumps, boilers, chillers, and water heating. Energy used by 120-volt equipment, or by 208/120-volt equipment that is located in a building where the main service is 480/277-volt power, is permitted to be

	excluded from total HVAC system energy use.
Interior lighting	Lighting systems located within the building.
Exterior lighting	Lighting systems located on the building site but not within the building.
Plug loads	Devices, appliances and equipment connected to convenience receptacle outlets.
Process load	Any single load that is not included in HVAC, lighting or plug load category and that exceeds 5 percent of the peak connected load of the whole building, including but not limited to data centers, manufacturing equipment, and commercial kitchens.
Electric vehicle charging	*Electric vehicle* charging loads.
Building operations and other miscellaneous	The remaining loads not included in this table, including but not limited to vertical transportation systems, automatic doors, motorized shading systems, ornamental fountains, ornamental fireplaces, swimming pools, in-ground spas and snow-melt systems.

Add new sections as follows:

C405.14 Electric vehicle charging infrastructure. Parking facilities shall be provided with electric vehicle charging infrastructure in accordance with this section and Table C405.14 based on the total number of parking spaces and rounded up to the nearest whole number*. EVSE, EV ready spaces* and *EV capable spaces* may be counted toward meeting minimum parking requirements. *EVSE spaces* may be used to meet requirements for *EV ready spaces* and *EV capable spaces. EV ready spaces* may be used to meet requirements for *EV capable spaces.* An *ALMS* may be used to reduce the total electrical capacity required by *EVSE spaces* provided that all *EVSE spaces* are capable of simultaneously charging at a minimum rate of 1.4 kW. Where more than one parking facility is provided on a building site, the number of parking spaces required shall be calculated separately for each parking facility.

> **Exception:** In parking garages, the conduit required for *EV capable spaces* may be omitted provided the parking garage electrical service has no less than 1.8 kVA of additional reserved capacity per *EV capable space.*

TABLE C405.14
ELECTRIC VEHICLE CHARGING INFRASTRUCTURE REQUIREMENTS

OCCUPANCY	***EVSE SPACES***	***EV READY SPACES***	***EV CAPABLE SPACES***
Group B Occupancies	15%	NA	40%
Group M Occupancies	25%	NA	40%
R-2 Occupancy	NA	100%[a]	NA
All other Occupancies	10%	NA	40%

a. Or one *EV ready space* per *dwelling unit.*

C405.14.1 EV Capable Spaces. *EV Capable Spaces* shall be provided with electrical infrastructure that meets the following requirements:

1. Conduit that is continuous between a junction box or outlet located within 3 feet (914 mm) of the parking space and an electrical panel serving the area of the parking space
2. The electrical panel to which the conduit connects shall have sufficient dedicated physical space for a dual-pole, 40-amp breaker

3. The conduit shall be sized and rated to accommodate a 40-amp, 208/240-volt branch circuit and have a minimum nominal trade size of 1 inch
4. The electrical junction box and the electrical panel directory entry for the dedicated space in the electrical panel shall have labels stating "For future *electric vehicle* charging"

C405.14.2 EV Ready Spaces. The branch circuit serving *EV Ready Spaces* shall meet the following requirements:

1. Wiring capable of supporting a 40-amp, 208/240-volt circuit,
2. Terminates at an outlet or junction box located within 3 feet (914 mm) of the parking space,
3. A minimum capacity of 1.8 kVA.
4. The electrical panel directory shall designate the branch circuit as "For electric vehicle charging" and the junction box or receptacle shall be labelled "For electric vehicle charging,"

C405.14.2 EVSE Spaces. The *EVSE* serving *EVSE spaces* shall be capable of supplying not less than 6.2 kW to an electric vehicle and shall be located within 3 feet (914 mm) of the parking space.

Energy Monitoring Requirements: Commercial Code

It is critical that LARA add the energy monitoring requirements from the 2021 IECC model code, which were removed from the draft, back into Michigan's final commercial energy code. Removing this requirement would significantly impede commercial building owners from maintaining their high-performance buildings at the level originally designed, losing out on cost savings. According to a report from the American Council for an Energy-Efficient Economy focused on energy management in industrial and commercial facilities, some programs are capable of saving building owners between two and five percent annually.[10] Building energy performance, if not properly monitored and maintained, erodes over time, and therefore energy monitoring, in addition to commissioning, would ensure the level of energy efficiency, as designed, is met over the life of the building. If LARA decides

[10] American Council for an Energy-Efficient Economy. "Energy Management Proves Cost Effective in Industrial and Commercial Facilities." May 6, 2021. Available at https://www.aceee.org/press-release/2021/05/energy-management-proves-cost-effective-industrial-and-commercial-facilities.

to maintain the removal of this important part of the 2021 IECC model code from Michigan's commercial energy code, it has the very real potential to erode much of the carbon impact of the new code as the energy savings associated with the new commercial buildings will not be maintained over time. Additionally, the energy monitoring requirements would provide tremendous data sets for energy management professionals to study and improve both the predictive energy modeling efforts in the design phase and the retro-commission process post building occupancy.

Michigan EIBC recommends LARA add Section 405.12 to C405. 12.5 from the IECC 2021 code back into the state's commercial energy code, which requires energy monitoring for buildings over 25,000 square feet.

Conclusion

Thank you for the opportunity to comment on the importance of improving Michigan's energy code. To reiterate, Michigan EIBC is strongly supportive of the advancements the second drafts have already made toward improving energy efficiency of Michigan's homes and buildings, and it is necessary that these advancements remain as LARA makes additional EV charging and energy monitoring improvements to the residential and commercial energy codes. We look forward to working with you throughout the remainder of this process.

Thank you,

Michigan EIBC

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BERNARDO A. BALLESTEROS

July 1, 2022

VIA EMAIL

Ms. Amanda Johnson, Rules Analyst
LARA/Bureau of Construction Codes
Administrative Services Division
P.O. Box 30254
Lansing, MI 48909

Re: 2021 Energy Code

Dear Ms. Johnson:

Included in this email is a Position Statement with ten Exhibits submitted on behalf of the Home Builders Association of Michigan ("HBAM"). HBAM is submitting the attached Position Statement, its references and attachments as part of the administrative record of the July 5, 2022 Public Hearing on the 10 Michigan Energy Code (ORR #2021-48 LR). Any questions related to this submission can be directed to either the undersigned or Bob Filka, CEO, Home Builders Association of Michigan, 6427 Centurion, Suite 100, Lansing, MI 48917; bob@hbaofmichigan.com; 517-646-2555.

Thank you for your consideration.

Very truly yours,

Melissa A. Hagen
mhagen@malansing.com

MAH/caj
cc w/enc:
Mr. Robert Filka
Mr. Lee Schwartz
Ms. Dawn Crandell
Mr. Forrest Wall

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Position Statement
on Behalf of Home Builders Association of Michigan

I. Introduction

The Home Builders Association of Michigan ("HBAM") is a statewide association whose members develop and build single-family residential homes and communities throughout Michigan. HBAM submits this Position Statement in opposition to the adoption of amendments to the Michigan Energy Code residential rules (Part 10), R 408.31001 - R 408.31086, by the Michigan Department of Licensing and Regulatory Affairs ("LARA"), Bureau of Construction Codes ("BCC"). The proposed amendments are posted at LARA's website and are incorporated by reference. HBAM objects to the amendments both substantively and procedurally because they fail to comply with the State Construction Code Act ("CCA") and the Administrative Procedures Act ("APA"). More specifically, among other things, LARA is amending the wrong code and/or has no statutory authority to amend the Michigan Energy Code, Part 10. In addition, the proposed rule changes do not comply with the statutory requirement of the CCA that the proposed amendments be "cost-effective," as that term is defined within the CCA. Further, the proposed amendments violate Michigan and federal law by creating a negative disparate impact on minority homebuyers. And, finally, the Regulatory Impact Statement ("RIS") authored and published by LARA fails to meet the statutory requirements of the APA. HBAM submits this Position Statement, its references and attachments as part of the administrative record of the July 5, 2022, Public Hearing on the Michigan Uniform Energy Code amendments.

In order to properly analyze the deficiencies of the proposed Michigan Energy Code, Part 10 amendments, HBAM retained Cayalyst Consulting, LLC to review and determine the accuracy of the RIS and LARA's assertions that the amendments are cost-effective within the meaning of Michigan law. For purposes of providing that analysis, Cayalyst Consulting, LLC examined the legislative and administrative history of the Council of American Buildings Officials Model Energy Code, the Michigan Uniform Energy Code, the Stille-DeRossett-Hale Single State Construction Code Act, the Michigan Residential Code and the Michigan Energy Code as well as a series of studies on the cost-effectiveness of Michigan's energy efficiency requirements. Cayalyst Consulting, LLC's analysis found numerous errors, inaccuracies, as well as incomplete answers in the RIS, many of which are material in nature to the promulgation of these amended rules.[1]

II. Historical Background

A. The Michigan Codes

In May 1995, Michigan adopted a new version of the CCA, which included new energy conservation standards taken from the Council of American Building Officials Model Energy Code. HBAM opposed these standards as being too restrictive and negatively impacting the availability of affordable housing. That same year, the Legislature responded by rescinding the adoption of the Model Energy Code, 270 PA 1995, effective January 8, 1996, and adding specific objectives and standards for the state construction code, including:

- To provide standards and requirements for **cost-effective energy efficiency** that will be effective April 1, 1997.
- Upon periodic review, to continue to seek ever-improving, **cost-effective energy efficiencies**.

The State Construction Code Commission established a 10-member ad hoc committee to draft Michigan's new cost-effective energy code. Following the requirements of Michigan's Administrative Procedures Act ("APA") and approval by the Legislature's Joint Committee on Administrative Rules ("JCAR"), the Michigan Uniform Energy Code Part 10 Rules were adopted.

[1] The principal of Cayalyst Consulting, LLC is Mr. Lee Schwartz, whose background and credentials are attached as Exhibit 1 and incorporated by reference.

The Michigan Uniform Energy Code was a "home-grown" code; that is, not simply a wholesale adoption of some nationally or internationally recognized code. This changed in 1999, however, with the adoption and statewide application of a State Construction Code (the "Code") through amendments to the CCA. 245 PA 1999. Among other changes, PA 245 specified components of the Code itself, as follows:

> [T]he code shall consist of the international residential code, the international building code, the international mechanical code, the international plumbing code published by the international code council, the national electrical code published by the national fire prevention association, and the Michigan uniform energy code with amendments, additions, or deletions as the director determines appropriate.

245 PA 1999, Sec 4(2). Importantly, PA 245 amended the CCA to define "cost-effectiveness" and mandate statutorily-required analyses for determining cost-effectiveness. 245 PA 1999, Sec 2(1)(n).

In 2012, the CCA was amended again. 504 PA 2012. Changes included:

1. The Michigan Uniform Energy Code was eliminated as a component of the "Code" and replaced with the International Energy Conservation Code [MCL 125.1504(2)];[2]

2. The Director of LARA was now required to update the Michigan Building Code, the Michigan Mechanical Code, the Michigan Plumbing Code, the Michigan Rehabilitation Code, the Michigan Electrical Code *and the commercial chapters of the Michigan Energy Code* not less than once every 3 years to coincide with the national code change cycle [MCL 125.1504(5)];[3]

3. Beginning with the 2015 national code change cycle, LARA is required to "simultaneously update all chapters of the Michigan Residential Code" at least once

[2] As discussed below, per its Request for Rulemaking and Regulatory Impact Statement, LARA purports to be amending the Michigan Uniform Energy Code in these proceedings. However, the Michigan Uniform Energy Code no longer exists and is not part of the Michigan Building Code.

[3] As also discussed below, per its Request for Rulemaking and Regulatory Impact Statement, LARA cites this provision of the CCA as authority for amending the residential chapters of the Michigan Uniform Energy Code. Subsection (5) of Section 4 of the CCA, however, only applies to the *commercial* chapters and, even then, only to the commercial chapters of the Michigan Energy Code (not the Michigan *Uniform* Energy Code).

every 6 years but not more often than once every 3 years. [MCL 125.1504(6)];[4] and

4. The definition of cost-effectiveness was amended to provide for additional statutorily mandated analyses that LARA must perform in order to amend the Code in compliance with Michigan law as follows:

   (p) "Cost-effective", in reference to section 4(3)(f) and (g), means, using the existing energy efficiency standards and requirements as the base of comparison, the economic benefits of the proposed energy efficiency standards and requirements will exceed the economic costs of the requirements of the proposed rules based upon an incremental multiyear analysis that meets all of the following requirements:

   (i) Considers the perspective of a typical first-time home buyer.

   (ii) Considers benefits and costs over a 7-year time period.

   (iii) Does not assume fuel price increases in excess of the assumed general rate of inflation.

   (iv) Ensures that the buyer of a home who would qualify to purchase the home before the addition of the energy efficient standards will still qualify to purchase the same home after the additional cost of the energy-saving construction features.

   (v) Ensures that the costs of principal, interest, taxes, insurance, and utilities will not be greater after the inclusion of the proposed cost of the additional energy-saving construction features required by the proposed energy efficiency rules that under the provisions of the existing energy efficiency rules. [MCL 125.1502a.]

In 2015, Michigan adopted the 2015 International Energy Conservation Code as the 2015 Michigan Energy Code. LARA is now attempting to replace the 2015 Michigan Energy Code with the 2021 International Energy Conservation Code.

B. The "I-Codes"

Michigan currently relies primarily on International Codes for the substance of its Michigan Codes. These International Codes ("I-Codes") are developed by the International Code

[4] As discussed below, the Michigan Residential Code includes the residential energy code at Chapter 11 which, according to its Request for Rulemaking and Regulatory Impact Statement, LARA is not amending, resulting in conflicting and/or ineffective building code requirements.

Council ("ICC").[5] The I-Codes consist of a family of fifteen coordinated, modern, model building safety codes that help ensure the engineering of safe, sustainable, affordable, and resilient structures. These model codes are then altered and amended by the adopting jurisdictions to fit the needs of that jurisdiction.

A preponderance of jurisdictions, including Michigan, adopt amended versions of the I-Codes including the International Energy Conservation Code ("IECC") and the International Residential Code ("IRC"). These amended versions are then published by ICC under the jurisdiction's name; e.g., the Michigan Residential Code. The ICC retains the copyright to these amended versions.

One of the salient features of the I-codes is the existence of two residential energy efficiency codes: the IECC's Chapter Four Residential Energy Efficiency and the IRC's Chapter 11 Energy Efficiency. As explained by the ICC on its website (www.iccsafe.org), the IRC is a "**comprehensive, stand-alone residential code"** which "establishes minimum regulations for one- and two-family dwellings and townhouses using prescriptive provisions. It is founded on broad-based principles that make possible the use of new materials and new building designs." In particular, the IRC contains "a **complete set of code provisions**, covering all aspects of construction in a single source, including:

- o Building
- o **Energy conservation**
- o Plumbing
- o Mechanical
- o Fuel gas provisions included through an agreement with the American Gas Association
- o Electrical provisions from the 2017 National Electrical Code® (NFPA 70)"

[5] The ICC was established in 1994, with the goal of developing a single set of national model construction codes. It brought together three different organizations that had developed three separate sets of model codes throughout the U.S: Building Officials and Code Administrators International, Inc., International Conference of Building Officials and Southern Building Code Congress International, Inc.

Not every jurisdiction adopts a residential code. In those cases where the IRC is not adopted, one- and two-family homes and townhouses are built under the provisions of the International Building Code ("IBC") and Chapter Four of the IECC. The residential requirements of the IECC, however, apply only to residential buildings that are ***not*** built under the IRC.

Michigan has adopted the 2015 IRC with amendments as its Michigan Residential Code ("MRC"). Michigan has adopted the 2015 IECC as its Michigan Energy Code ("MEC"). The currently proposed amendments, however, are for the MEC only – not the MRC.

III. LARA is Amending the Wrong Code and/or Has No Statutory Basis to Amend Part 10 of the Michigan Energy Code

The Request for Rulemaking and the RIS both indicate that the currently proposed amendments are to Part 10 of the Michigan *Uniform* Energy Code. This is incorrect.

First, there is no Michigan *Uniform* Energy Code. That code was eliminated with the 1999 amendments to the CCA. Michigan currently uses the MEC. The MEC, however, is not what is referenced in the public notification documents that are required by the Michigan Administrative Procedures Act before any changes or additions to rules. MCL 24.239(1); MCL 24.245(3).

Second, there is no statutory authority that permits amendments to Part 10 (residential) of the MEC as currently adopted. The provision of the CCA related to amending the Codes is MCL 125.1504; specifically, subsections (5) and (6). With respect to the MEC, its commercial provisions (Part 10a) are to be amended on a 3-year cycle, pursuant to MCL 125.1504(5). However, there is no mention of amendment of the residential provisions (Part 10) in either subsection (5) or (6) of MCL 125.1504. As a result, there is no statutory authority whatsoever which either permits or requires the amendment of the current residential (Part 10) MEC. Accordingly, LARA's actions thus far to amend Part 10 of the MEC and any actions taken hereafter, are simply not authorized by Michigan law.

Third, as discussed, there are two sections of two Codes in Michigan related to energy conservation in residential construction – Part 10 of the MEC and Chapter 11 of the MRC. Both of these Codes purport to cover construction of single- and two-family dwellings. In this proceeding, however, LARA is amending only Part 10 of the MEC and not Chapter 11 of the MRC.[6] Obviously, at a minimum, LARA's failure to include Chapter 11 of the MRC creates the potential for conflicting standards, procedures and requirements between the two Codes. At worst, this failure renders the amendments nugatory. The International Residential Code, adopted as the MRC, states that where provisions of the International Residential Code conflict with other referenced codes or even the subject matter of another code, the provisions of the International Residential Code take precedence. IRC/MRC 102.4.1.[7]

IV. Evaluation of the Proposed Amendments Vis-a-Vis the Cost-Effectiveness Requirements of the CCA by Cayalyst Consulting, LLC

The CCA requires that the Code be designed to provide standards and requirements for energy efficiencies that are "cost-effective." MCL 125.1504(3)(f). The purpose for the CCA's mandatory cost-effective provisions for energy efficiency rules is to protect obtainable housing. The cost-effectiveness test was specifically included in the CCA by the Michigan Legislature to protect home affordability and avoid unnecessary fiscal burdens on individuals. The CCA defines "cost-effective" as follows:

> (p) "Cost-effective", in reference to section 4(3)(f) and (g), means, using the existing energy efficiency standards and requirements as the base of comparison, the economic benefits of the proposed energy efficiency standards and requirements will exceed the

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[6] That the currently proposed amendments do not apply to Chapter 11 of the Michigan Residential Code is apparent from LARA's recent opening of the entire 2021 Residential Code for proposals/code change requests which LARA proposes to adopt in replacement of the 2015 Michigan Residential Code. See, LARA Residential Code Notice, Exhibit 2.

[7] Specifically, IRC/MRC 102.4.1 provides:

> Where conflicts occur between provisions of this code and referenced codes and standards, the provisions of this code shall apply.

> economic costs of the requirements of the proposed rules based upon an incremental multiyear analysis that meets all of the following requirements:
>
> (i) Considers the perspective of a typical first-time home buyer.
>
> (ii) Considers benefits and costs over a 7-year time period.
>
> (iii) Does not assume fuel price increases in excess of the assumed general rate of inflation.
>
> (iv) Ensures that the buyer of a home who would qualify to purchase the home before the addition of the energy efficient standards will still qualify to purchase the same home after the additional cost of the energy-saving construction features.
>
> (v) Ensures that the costs of principal, interest, taxes, insurance, and utilities will not be greater after the inclusion of the proposed cost of the additional energy-saving construction features required by the proposed energy efficiency rules than under the provisions of the existing energy efficiency rules.

MCL 125.1502a. Thus, the CCA requires, without exception, that LARA demonstrate that the economic benefits of the new energy standards exceed the economic costs of the new energy standards <u>based on an incremental multi-year analysis</u> that considers and addresses the perspective of a typical first-time home buyer and benefits and costs over a 7-year time period.

LARA must also demonstrate in its analysis that it did not assume fuel price increases in excess of the assumed general rate of inflation. And, LARA must "*ensure*" that qualified home buyers are not "priced-out" by the new energy standards and that the costs of principal, interest, taxes, insurance, and utilities will not be greater after the inclusion of the proposed cost of the additional energy-saving construction features required by the proposed energy efficiency rules than under the provisions of the existing energy efficiency rules.

LARA has neither met this burden of proof, nor can it meet this burden of proof, because the proposed amendments are not "cost-effective" within the meaning of the CCA. In particular, LARA has failed to provide any data or evidence to prove the proposed rules meet ***any*** of these requirements. In fact, at its Public Advisory Meeting, LARA was provided with three studies conducted by three different organizations skilled in the analysis of energy efficiency. As discussed in detail below, these studies show that the proposed rules are not "cost-effective" under Michigan law.[8]

A. PNNL Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan

At its Public Advisory meetings, LARA was provided with a copy of the U.S. Department of Energy's ("DOE") July 2021 "*Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan"* study (the "PNNL Study"). The study was conducted by Pacific Northwest National Laboratory ("PNNL"). PNNL is a leading center for scientific discovery in chemistry, data analytics, and Earth science, and for technological innovation in sustainable energy and national security**.** A copy of the PNNL Study is attached as Exhibit 3 and incorporated by reference.

The PNNL Study states "*The 2021 IECC provides cost-effective levels of energy efficiency and performance for residential buildings."* However, it does **not follow the requirements of**

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[8] Before examining the studies, it is important to understand that the 2021 IECC requires the use of one of five additional efficiency "packages" as well as any of the three compliance approaches (Prescriptive, Performance or Energy Rating Index).

These packages are:

- Enhanced Envelope Performance
- More Efficient HVAC equipment
- Reduced energy use in service water-heating
- More Efficient Duct Thermal Distribution System Option
- Improved Air Sealing and Efficient Ventilation System

Michigan law to make this determination but instead uses its own methodology for determining cost-effectiveness.

Michigan law requires a 7-year simple payback as one of the <u>**five**</u> measures required to be met to prove cost-effectiveness. **The PNNL Study reported the following Simple Payback Periods for the 2021 IECC compared to the 2015 IECC with amendments:**

> **Climate Zone 5A … 12.0 years**
> **Climate Zone 6A … 10.7 years**
> **Climate Zone 7 … 10.5 years**

Accordingly, rather than proving the assertion that adopting the 2021 International Energy Code without amendments meets the requirements for cost-effectiveness found in the CCA, the PNNL Study proves the opposite. The economic benefits of the proposed energy efficiency standards and requirements of adopting the 2021 IECC without amendments will NOT exceed the economic costs of adopting the 2021 IECC without amendments. Additionally, the PNNL Study did not address the mandatory tests found in items (iv) and (v) of Michigan's cost-effectiveness requirements.

To explain what it does and does not do, page one of the PNNL Study recites the DOE's cost-effective requirements. These make clear that the conclusion that the 2021 IECC is cost-effective does not meet Michigan law.

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

> ***LCC savings is the primary metric established by the U.S. Department of Energy (DOE)to assess the economic impact of residential building energy codes.*** (emphasis added) *Simple payback period and the Consumer Cash Flow analysis are reported to provide additional information to stakeholders, including states which have established a range of alternative economic metrics*. (Emphasis added.)

The PNNL Study also states,

> *Both the LCC savings and the year-by-year cash flow values from which it is calculated assume that initial costs are mortgaged, that homeowners take advantage of mortgage interest tax deductions, that individual efficiency measures are replaced with like measures at the end of their useful lifetimes and that all efficiency measures with useful life remaining at the end of the 30-year period of analysis retain a residual value at that point.*

(Emphasis added.) That is, for equipment that still has life remaining at the end of the analysis period, the *resale value* (often called "*residual value*") of that equipment is included in the last year of the analysis. The resale value is based on the percentage of life left in the equipment and the first cost of that piece of equipment.

Page 3 of the PNNL Study explains the simple payback period:

> *The simple payback period is a straightforward metric including only the costs and benefits directly related to the implementation of energy-savings measures associated with a code change. … Because it focuses on the two primary characterizations of a code change – cost and energy performance— it allows an assessment of cost-effectiveness that is easy to compare with other investment options and requires a minimum of input data.* ***DOE reports the simple payback period because it is a familiar metric used in many contexts and because some states have expressed the desire for this metric.***

(Emphasis added.) Michigan is one of those states.

The PNNL Study also assumes that if one of the required additional options is cost-effective using a 30-year LCC metric, no further analysis of the remaining options needs to be conducted. Thus, there is no individual analysis of the "additional energy packages" required by the 2021 IECC in the PNNL Study. In sum, the conclusion by the PNNL Study that the 2021 IECC is cost-effective does not meet the definition of "cost-effective" under Michigan law.

B. Home Innovation Research Labs 2021 IECC Residential Cost-Effective Analysis

Home Innovation Research Labs is a full-service research, testing, and consulting firm determined to improve the quality, durability, affordability, and environmental performance of single- and multifamily homes and home building product. Commissioned by the National Association of Home Builders, the Home Innovations Research Labs' ("HIRL") *2021 IECC Residential Cost Effective Analysis* (the "HIRL Study"), conducted a more thorough analysis of the differing configurations and options found in the 2021 IECC. The simple payback period results of this study are relevant to Michigan. A copy of the HIRL Study is attached as Exhibit 4 and incorporated by reference. LARA was provided with a copy of the HIRL Study at its public advisory meeting.

Using the 2021 IECC without additional efficiency options, the required simple payback period was:

Climate Zone 5 … 61 years
Climate Zone 6 … 47 years
Climate Zone 7 … 78 years

Using the HVAC option, the simple payback period was:

Climate Zone 5 … 32 years
Climate Zone 6 … 19 years
Climate Zone 7 … 24 years

Using the water heater option, the simple payback period was:

Climate Zone 5 … 54 years
Climate Zone 6 … 19 years
Climate Zone 7 … 79 years

Using the ventilation option, the simple payback period was:

Climate Zone 5 … 68 years
Climate Zone 6 … 50 years
Climate Zone 7 … 63 years

Using the duct option in a slab-on-grade home, the simple payback period was:

Climate Zone 5 … 68 years
Climate Zone 6 … 50 years
Climate Zone 7 … 63 years

These simple payback periods are not in compliance with Michigan law, which requires a simple 7-year payback.

C. ICF Cost Effectiveness of the Residential Provisions of the 2021 IECC

To rebut the HIRL Study, the Energy Efficient Codes Coalition contracted with ICF, a global consulting services company to produce the "ICF Study," to "*check the math of the HIRL report.*" A copy of the ICF Study is attached as Exhibit 5 and incorporated by reference. While the ICF Study accepted the energy savings from the HIRL Study, it "*updated*" material and labor costs (in some cases determining there were "*no incremental cost increases*") and "*revised*" the building geometry of the "*standard reference house*" used in the HIRL Study. Accordingly, rather than "*checking the math*" of the HIRL Study, ICF created and used a set of values in its calculations which significantly differed from both the PNNL Study and the HIRL Study.

In the section entitled "*Conclusions*," the ICF Study states the following:

> *The HIRL report was analyzed and <u>updated with new costs for code changes</u> based on publicly available sources and cost-effectiveness was reexamined <u>using metrics from the DOE Methodology that is used to evaluate the cost-effectiveness of code changes (i.e. Life-Cycle Cost)</u>.*

The ICF's conclusion section went on to note:

> *The 2021 IECC is cost-effective when compared to the 2018 IECC across all climate zones and there are multiple cost-effective compliance options in each climate zone. ... Individual code changes to the 2021 IECC have varying ranges of simple payback, but overall, the IECC is cost-effective….*

A chart at page 9 shows Simple Payback relative to the 2018 Baseline Reference House.

According to ICF's analysis for the IECC, the simple payback periods are as follows:

Using the 2021 without additional efficiency package options, the simple payback periods are:

Climate Zone 5 --- 22 years
Climate Zone 6 --- 4 years
Climate Zone 7 --- 25 years

Using the HVAC option, the simple payback periods are:

Climate Zone 5 --- 13 years
Climate Zone 6 --- 5 years
Climate Zone 7 --- 10 years

Using the Water Heater option, the simple payback periods are:

Climate Zone 5 --- 21 years
Climate Zone 6 --- 8 years
Climate Zone 7 --- 28 years

Using the Ventilation option, the simple payback periods are:

Climate Zone 5 --- 28 years
Climate Zone 6 --- 15 years
Climate Zone 7 --- 20 years

Using the duct option in a slab-on-grade home, the simple payback periods are:

Climate Zone 5 … 16 years
Climate Zone 6 … 4 years
Climate Zone 7 … 8 years

In other words, as demonstrated by that measure, the ICF Study also concludes that the 2021 IECC is not cost-effective by Michigan's standards.

D. RMI *Economic Analysis of Proposed Residential Code Amendments*

RMI is a non-partisan, non-profit organization that "works to transform global energy systems across the real economy." New Buildings Institute ("NBI") works collaboratively with industry market players – governments, utilities, energy efficiency advocates and building professionals – to promote advanced design practices, innovative technologies, public policies and programs that improve energy efficiency at the highest levels and decarbonize the built environment.

NBI and RMI conducted a study in which they analyzed the economic effects of adopting a series of amendments proposed by the two organizations (the "RMI Study"). The RMI Study does not show that adopting the 2021 IECC without those amendments would meet the cost-effective requirements of Michigan law; it makes no attempt to do so. A copy of the RMI Study is attached as Exhibit 6.

E. ConSol Impact of the 2021 IECC on 2015 Michigan Residential Code

ConSol is a California-based company with 35 years of expertise in energy efficiency, the building industry, energy codes, construction practices and emerging technologies. HBAM contracted with ConSol, to analyze the cost implications of the adoption of the requirements of the 2021 IECC in place of Chapter 11 of the 2015 Michigan Residential Code. The "ConSol Impact Study" is attached as Exhibit 7 and incorporated by reference.

The ConSol Impact Study modeled the energy use of a single-story and a two-story home in each of Michigan's three climate zones to calculate the initial costs, utility bill reductions, and payback periods of the significant changes between the current Michigan Energy Code and the 2021 IECC.

The ConSol Impact Study resulted in the following Simple Payback Periods:

SINGLE-STORY HOME

Using the 2021 without additional efficiency package options:

Climate Zone 5 --- 33 years
Climate Zone 6 --- 24 years
Climate Zone 7 --- 36 years

Using the HVAC option:

Climate Zone 5 --- 18 years
Climate Zone 6 --- 18 years
Climate Zone 7 --- 23 years

Using the Water Heater option:

Climate Zone 5 --- 28 years
Climate Zone 6 --- 22 years
Climate Zone 7 --- 38 years

Using the Ventilation option:

Climate Zone 5 --- 64 years
Climate Zone 6 --- 53 years
Climate Zone 7 --- 23 years

Using the duct option in a slab-on-grade home:

Climate Zone 5 … 30 years
Climate Zone 6 … 21 years
Climate Zone 7 … 18 years

TWO-STORY HOME

Using the 2021 without additional efficiency package options:

Climate Zone 5 --- 17 years
Climate Zone 6 --- 24 years
Climate Zone 7 --- 28 years

Using the HVAC option:

Climate Zone 5 --- 19 years
Climate Zone 6 --- 13 years
Climate Zone 7 --- 18 years

Using the Water Heater option:

Climate Zone 5 --- 23 years
Climate Zone 6 --- 17 years
Climate Zone 7 --- 29 years

Using the Ventilation option:

Climate Zone 5 --- 60 years
Climate Zone 6 --- 53 years
Climate Zone 7 --- No savings $2 per year increased energy bill

Using the duct option in a slab-on-grade home:

Climate Zone 5 … 26 years
Climate Zone 6 … 17 years
Climate Zone 7 … 26 years

In sum, the ConSol Impact Study shows that the 2021 IECC is not cost-effective under Michigan's statutory standards.

F. Conclusion

In conclusion, with the exception of the anomalous payback periods for Climate Zone 6 in the ICF Study, ***all of the studies relied on by LARA and the ConSol Impact Study commissioned by HBAM refute the assertion that adoption of the 2021 IECC in Michigan meets the 7-year simple payback period required to establish cost-effectiveness under Michigan law.***

V. The Proposed Amendments Will have a Disparate Impact Upon Minority Home Buyers

The Fair Housing Act, 42 USC §§3601-3619 and 3631 (the "FHA"), protects home buyers against discrimination. More specifically, and as relevant here, the FHA makes it illegal to discriminate against any person in terms, conditions or privileges of sale because of race, color or national origin. 42 USC §3604(b).[9] This includes liability based on disparate impact. *Texas Dep't*

[9] The same is true under Michigan law. MCL 37.2502(1)(b).

of Housing & Community Affairs v The Inclusive Communities Project, Inc., 573 US 991; 135 S Ct 46; 189 L Ed 2d 896 (2014); *Arthur v City of Toledo*, 782 F2d 565, 574-575 (CA 6, 1986). Therefore, where a decision, policy or regulation has a discriminatory effect that makes housing options more restrictive for members of a protected group than for persons outside that group, the FHA has been violated. *Hallmark Developers Inc v Fulton Co, Ga,* 466 F3d 1276 (CA 11, 2006). And, where higher prices reduce the size of the purchaser market of a protected group, the Fair Housing Act has been violated. *Reinhart v Lincoln Co,* 482 F3d 1225 (CA 10, 2007). Similarly, where higher prices disproportionately affect lower income families, the composition of which are predominantly minorities, the FHA is violated. *Gallagher v Magnes,* 619 F3d 823 (CA 8, 2010); *US v City of Black Jack Missouri*, 508 F2d 1179 (CA 8, 1975).

Here, compliance with the proposed amendments will add approximately $5,181 to the cost of a new home. A study commissioned by the National Association of Home Builders ("NAHB"), completed in February 2022, shows, by State and Metro Area, how many households will be unable to purchase a home ("priced out of the housing market") in 2022, with only a $1,000 home price increase (the "NAHB Study"). In Michigan, an estimated 5,445 households will be priced out of the housing market by only a $1,000 price increase. See, NAHB Study, Exhibit 8. Obviously, that amount is drastically higher when the cost increase is five times the $1,000 amount used in the NAHB Study.

Further, a second NAHB analysis of housing affordability based on race and ethnicity shows a wide disparity in the number of households that can afford a new median priced home. The "NAHB Study #2," attached as Exhibit 9, states:

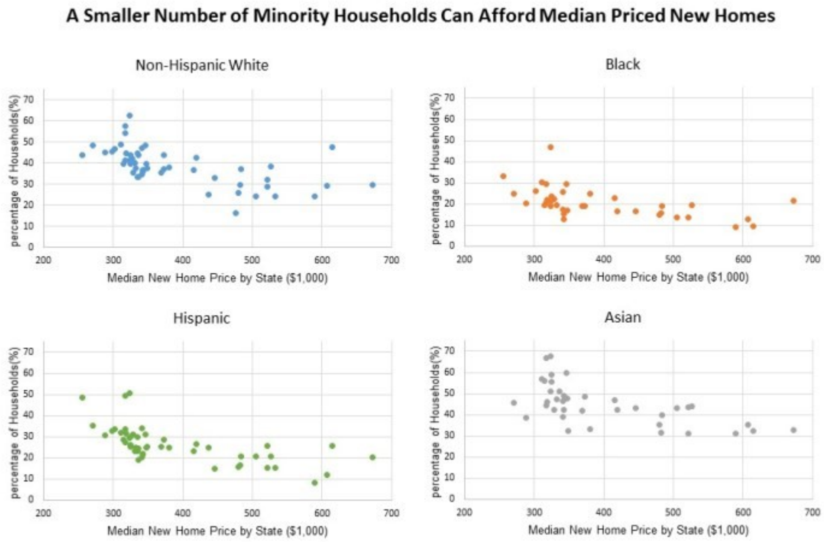
> At the national level, the share of Black households that are able to afford the new homes is substantially lower than the share of non-Hispanic white households. Only 24% of Black households are able to afford the median new U.S. price of $346,577.

Among non-Hispanic white households, 44% have sufficient income to qualify for a mortgage for a new median priced home under standard underwriting criteria, compared to 56% of Asian households and 32% of Hispanic households.

The number of households being priced out of the market due to a $1,000 price increase varies among different racial/ethnical groups but is more or less proportional to population size. The largest priced-out number as a result of a $1,000 price increase is 106,278 for non-Hispanic white households, which accounts for around 67% of total U.S. households. By contrast, the number of Black and Hispanic households that would be priced out the market due to a $1,000 price hike are 15,840 and 21,376, respectively.

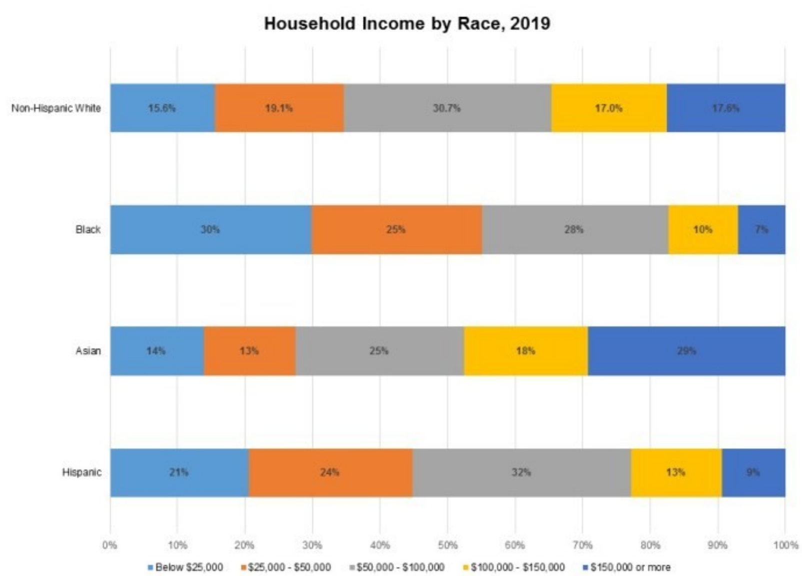
The affordability gaps between non-Hispanic white households and minority households are persistent across all states and are in fact larger in states where new home prices are relatively more affordable. The share of households that are able to afford new homes is largely affected by the state's median new home prices. And too often, more affordable markets does not mean that housing is equally affordable to all ethnic groups.

As indicated in the chart below, the higher the home price is, the smaller the number of households that can afford new homes. In Nebraska, where the median new price is $288,401, the share of non-Hispanic white households that could afford new homes is 25 percentage basis points larger than the share of Black households, and 14 percentage basis points larger than Hispanic households. However, this gap is much smaller in Hawaii, with a new median home price of $672,314. In Hawaii, 30% of non-Hispanic white households are able to qualify for a mortgage for a new median priced home, compared with 21% for Black households and 20% for Hispanic households.



Note: The scatterplot presents the median new home price and the percentage of households that can afford new homes for each state.
Source: NAHB tabulations of 2021 priced-out estimates at the state level

The housing affordability story is also a reflection of underlying income data. Income plays a key role in housing affordability, in terms of budget and mortgage qualification. According to the 2019 American Community Survey, the median household income for non-Hispanic white households was $71,664, significantly higher than the $43,862 for Black households. The differences of income distribution among race/ethnicity are large, as shown in the figure below. Thirty percent of Black households have household income below $25,000 compared to 15.5% of non-Hispanic white households. Around 17.6% of non-Hispanic white households earn more than $150,000 while only 7% of Black households do.



Source: NAHB estimates, 2019 American Community Survey

In sum, it is reasonable to conclude, that the households primarily affected by increased housing costs will be on the lower income end of the spectrum. Statistics will demonstrate that lower income families are predominantly minorities. Therefore, the impact of the higher cost of housing will be disproportionately placed on minorities in violation of the FHA, and contrary to the laws and policies that the State of Michigan should follow and pursue.

VI. Evaluation of the Regulatory Impact Statement and Cost-Benefit Analysis by Cayalyst Consulting, LLC

Under the APA, any state agency amending a rule or rules must, among other things, prepare and transmit to the Michigan Office of Administrative Hearings and Rules ("MOAHR"), a regulatory impact statement. MCL 24.245(3) and (4).[10] The APA provides that a regulatory impact statement must contain all of the following information:

> (a) A comparison of the proposed rule to parallel federal rules or standards set by a state or national licensing agency or accreditation association, if any exist.
>
> (b) If section 32(8) applies and the proposed rule is more stringent than the applicable federally mandated standard, a statement of the specific facts that establish the clear and convincing need to adopt the more stringent rule and an explanation of the exceptional circumstances that necessitate the more stringent standard.
>
> (c) If section 32(9) applies and the proposed rule is more stringent than the applicable federal standard, either the statute that specifically authorizes the more stringent rule or a statement of the specific facts that establish the clear and convincing need to adopt the more stringent rule and an explanation of the exceptional circumstances that necessitate the more stringent standard.
>
> (d) If requested by the office or the committee, a comparison of the proposed rule to standards in similarly situated states,

[10] There are three exceptions to the regulatory impact statement requirement. MCL 24.245(6). In general, these exceptions pertain to rules describing the organization and methods of operation and an agency (MCL 24.233), emergency rules to protect public health (MCL 24.248), and rules for which a public hearing is not required (MCL 24.244). None of the exceptions apply here.

based on geographic location, topography, natural resources, commonalities, or economic similarities.

(e) An identification of the behavior and frequency of behavior that the rule is designed to alter.

(f) An identification of the harm resulting from the behavior that the rule is designed to alter and the likelihood that the harm will occur in the absence of the rule.

(g) An estimate of the change in the frequency of the targeted behavior expected from the rule.

(h) An identification of the businesses, groups, or individuals who will be directly affected by, bear the cost of, or directly benefit from the rule.

(i) An identification of any reasonable alternatives to regulation under the proposed rule that would achieve the same or similar goals.

(j) A discussion of the feasibility of establishing a regulatory program similar to that proposed in the rule that would operate through market-based mechanisms.

(k) An estimate of the cost of rule imposition on the agency promulgating the rule.

(l) An estimate of the actual statewide compliance costs of the proposed rule on individuals.

(m) A demonstration that the proposed rule is necessary and suitable to achieve its purpose in proportion to the burdens it places on individuals.

(n) An estimate of the actual statewide compliance costs of the proposed rule on businesses and other groups.

(o) An identification of any disproportionate impact the proposed rule may have on small businesses because of their size.

(p) An identification of the nature of any report required and the estimated cost of its preparation by small businesses required to comply with the proposed rule.

(q) An analysis of the costs of compliance for all small businesses affected by the proposed rule, including costs of equipment, supplies, labor, and increased administrative costs.

(r) An identification of the nature and estimated cost of any legal consulting and accounting services that small businesses would incur in complying with the proposed rule.

(s) An estimate of the ability of small businesses to absorb the costs estimated under subdivisions (p) to (r) without suffering economic harm and without adversely affecting competition in the marketplace.

(t) An estimate of the cost, if any, to the agency of administering or enforcing a rule that exempts or sets lesser standards for compliance by small businesses.

(u) An identification of the impact on the public interest of exempting or setting lesser standards of compliance for small businesses.

(v) A statement describing the manner in which the agency reduced the economic impact of the rule on small businesses or a statement describing the reasons such a reduction was not feasible.

(w) A statement describing how the agency has involved small businesses in the development of the rule.

(x) An estimate of the primary and direct benefits of the rule.

(y) An estimate of any cost reductions to businesses, individuals, groups of individuals, or governmental units as a result of the rule.

(z) An estimate of any increase in revenues to state or local governmental units as a result of the rule.

(aa) An estimate of any secondary or indirect benefits of the rule.

(bb) An identification of the sources the agency relied on in compiling the regulatory impact statement, including the methodology used in determining the existence and extent of the impact of a proposed rule and a cost-benefit analysis of the proposed rule.

(cc) A detailed recitation of the efforts of the agency to comply with the mandate to reduce the disproportionate impact of

> the rule on small businesses as described in section 40(1)(a) to (d).

MCL 24.245(3) (emphasis supplied). MOAHR's rules reduces these requirements to a standard form, setting out "Items" to be addressed by the department or agency proposing the rule.

On June 3, 2022 (updated June 9, 2022), LARA prepared and published its RIS for the currently proposed amendments to the MEC, Part 10. A copy of the June 9, 2022 RIS is attached as Exhibit 10 and is addressed below. There are serious deficiencies in the RIS: it does not comply with the APA and fails to provide the public or those directly regulated by the proposed rules fair notice of the purpose and effect of the changes.

A. The Responses to Items 2 and 2A of the RIS are in Error and are Incomplete

Item 2 requires that LARA compare the proposed rules to standards in similarly situated states, based on geographic location, topography, natural resources, commonalities, or economic similarities. If the rules exceed standards in those states, Item 2A requires the department to explain why and ***specify*** the costs and benefits arising out of the deviation.

In its answer to Item 2, the department stated:

> *All surrounding Great Lake States follow the International Energy Conservation Code, however Michigan's rules look to be more stringent and following the newer codes than compared to similar states.*

In its original answer to Item 2A, LARA stated:

> *The Michigan rules do exceed the standards of any of the other Great Lakes States. The surrounding Great Lakes States still follow the 2009 standard.*

In its revised answer to Item 2A, LARA stated: ". . . *the surrounding Great Lakes states still follow the 2007, 2010 and 2013 IECC*." Neither statement is accurate.

As taken from the ICC website on June 21, 2022:

1. Illinois uses an amended version of the 2018 IECC. It applies statewide and is the only statewide code allowed under Illinois law. All other building codes are adopted on the local level.

2. Indiana uses the 2020 Indiana Residential Code including an amended version of Chapter 11 of the IRC.

3. Minnesota uses the 2020 Minnesota Residential Code. Chapter 11's provisions for energy, energy conservation, or references to the International Energy Conservation Code are deleted and replaced with Minnesota Rules, Chapters 1322 and 1323, Minnesota Energy Codes.

4. New York uses the 2020 New York Residential Code including an amended Chapter 11.

5. Ohio uses the 2019 Ohio Residential Code including an amended version of Chapter 11 of the IRC.

6. Pennsylvania uses Uniform Construction Code (UCC) including an amended version of Chapter 11 of the IRC.

Accordingly, the RIS is simply incorrect as to Item 2. Additionally, the RIS is incomplete as it did not even attempt to specify ANY verifiable costs and benefits arising out of this deviation as required by Item 2A.

B. The Response to Item 3 of the RIS is Simply Wrong

Item 3 requires LARA to identify any laws rules, and other legal requirements that may duplicate, overlap, or **<u>conflict</u>** with the proposed rules. The RIS response in Item 3 states, "*There are no federal, state, or local laws or other legal requirements that may duplicate, overlap or conflict with the proposed rules.*"

This is incorrect. As shown earlier, the proposed rules conflict with the cost-effective requirements of the CCA. They also conflict with the Michigan Residential Code and the statutory authority of the CCA, if the proposed rules are applied to residential construction.

C. The Responses to Items 6, 6A and 6B of the RIS are Incomplete and the Items are Unanswered

Item 6 requires that LARA identify the behavior and frequency of behavior that the proposed rules are designed to alter. It fails to do so, simply stating the CCA requires that the department amend and rescind rules to update the IECC not less than once every 3 years. No behavior or frequency of behavior is identified. Information on what construction the rules affect would inform the public and the building industry and provide context for how the rules affect, or are intended to affect, construction and occupancy of new buildings.

Item 6A requires that LARA estimate the frequency of the targeted behavior expected from the proposed rules. Since LARA failed to identify the behavior and frequency the proposed rules are designed to alter, it fails to establish any frequency of the targeted behavior expected from the proposed rules. Instead, it simply repeats the statutory requirement to update the rules.

Item 6B requires that LARA describe the difference between current behavior/practice and desired behavior and practice. Again, LARA fails to answer the question simply repeating the requirement to update the code on a regular cycle. This subject is also exactly the point of the statutory rules for cost-effectiveness.

D. The Response to Item 6C of the RIS is Imprecise and Inaccurate

Item 6C requires LARA to explain the desired outcome of the proposed rules. By way of response, LARA stated three desired outcomes:

1. To bring the administrative application of the Energy Code rules in line with current and upcoming technology.

2. To eliminate unnecessary requirements in the code.

3. To have an easier interpretation and clarification of these rules.

Regarding outcome 1, the administrative portions of the IRC and the MRC already contain language allowing for the use of "*alternative materials, design, and methods of construction*."

> *The provisions of the code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by the code if the alternative has been approved. An alternative material, design, or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of the code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in the code.*

The CCA goes further stating:

> *If the Michigan residential code is updated on a 6-year cycle, the use of a material, product, method of manufacture, or method or manner of construction or installation provided for in an interim edition of the international residential code is authorized throughout this state and shall be permitted, but shall not be mandated, by an enforcing agency or its building official or inspectors. However, the enforcing agency or its building official or inspectors may require that if such a material, product, method of manufacture, or method or manner of construction or installation provided for in an interim edition of the international residential code is used, the use shall comply with all applicable requirements set forth in the interim edition of the international residential code.*

MCL 125.1504(8).

While LARA chose to <u>not</u> formally adopt the 2018 version of the International Residential Code, the use of any material, product, method of manufacture, or method or manner of construction or installation provided for in the 2018 edition of the International Residential Code, including Chapter 11 on energy efficiency, was and is authorized throughout Michigan. Allowing the use of current and future technology is already provided for in the Code, thus outcome one currently exists and cannot be used as justification for these proposed rules.

The second desired outcome, "[t]o eliminate unnecessary requirements in the code," is likewise not met. As posted for public hearing, the proposed rules rescind the current residential energy code in its entirety and replace it with the 2021 IECC. <u>Aside from twelve deletions in the administrative chapter, the rules contain no deletions to the 2021 IECC</u>. As a result, from all that appears, <u>LARA was unable to find a single requirement in the 2021 IECC it considered unnecessary</u>. This strongly calls into question LARA's assertion that the proposed rules are intended to eliminate unnecessary requirements in the Code.

The final outcome LARA says it desires to "*have an easier interpretation and clarification of these rules.*" This too has not occurred nor is it apparent how the proposed code might have that effect.

The ICC publishes a series of books with each new edition of the codes entitled "*Significant Changes*." The 2021 IECC contains nearly 200 changes from the 2018 edition of the code.

In the preface to "*Significant Changes to the International Energy Conservation Code, 2021 Edition*," the ICC offers the following guidance. "***<u>Only a portion</u>*** *of the total number of code changes to the IECC are discussed in this book. The changes selected were identified for a number of reasons, including the frequency of application, special significance or change in application. However,* ***<u>the importance of those changes not included is not to be diminished</u>***."

"*Significant Changes to the International Energy Conservation Code, 2021 Edition*," identifies these items among <u>72 pages</u> devoted to explanations of the following changes:

- Digital Plans
- Information of Construction Documents
- Definition of High-Efficacy Light Sources
- Definition of Renewable Energy Certificate
- Climate Zone Definitions
- Compliance Paths
- Certificates
- Building Envelope
- Insulation and Fenestration Criteria
- Insulation and Fenestration U-Factors

- Insulation Minimum R-Values and Fenestration Requirements by Component
- Basement Walls
- Air Leakage Testing
- Maximum Fenestration U-Factor and SHGC
- Systems
- Duct Location and Insulation
- Duct Testing
- Mechanical Ventilation System Testing
- Electric Power and Lighting Systems
- Exterior Lighting
- Interior Lighting Controls
- Exterior Lighting Controls
- Total Building Performance
- Performance-based Compliance
- Compliance Report
- Energy Rating Index Compliance Alternative
- ERI Compliance
- Additional Efficiency Package Options
    - Enhanced Envelope Performance
    - More Efficient HVAC equipment
    - Reduced energy use in service water-heating
    - More Efficient Duct Thermal Distribution System Option
    - Improved Air Sealing and Efficient Ventilation System
- Shading
- Zero Energy Residential Building Provisions

Given the number and substantial nature of these changes, the assertion that adopting the 2021 IECC would allow for the easier interpretation and clarification of Michigan's energy efficiency requirements is not supported.

There is an additional factor which calls LARA's response into question. At the present time, the promulgated energy codes in use in Michigan are Chapter 11 of the 2015 MRC and the 2015 IECC. LARA availed itself of the discretion given to it by MCL 124.1504(8) and did not update to the 2018 version of the IRC, choosing to maintain the 2015 MRC including its Chapter 11 energy efficiency requirements. Therefore, should LARA adopt the 2021 IECC, users of the code, including building officials and contractors, would not only have to attempt to interpret the 2021 changes but also those changes made from the 2015 code to the 2018 code.

The CCA, MCL 124.1504(8), gives LARA the authority to update only the residential code not more than every 3 years or not less than every 6 years. Under the CCA, LARA was required to update the commercial chapters of the IECC to the 2018 version, which it failed to do. The RIS does not address the omission.

E. The Response to Item 8 of the RIS is Evasive, Inaccurate and Leaves the Item 8 Unanswered

Item 8 requires that LARA describe how the proposed rules protect the health, safety and welfare of Michigan citizens while promoting a regulatory environment in Michigan that is the least burdensome alternative for those required to comply. In answer to this Item, LARA simply repeats the verbiage of the question, asserting the proposed rules will protect the health, safety and welfare of Michigan citizens while promoting a regulatory environment in Michigan that is the least burdensome alternative for those required to comply without providing any description or evidence this is true. This is totally non-responsive.

Further, LARA states that the rules are administrative in nature. While the proposed rules are being promulgated through the administrative rules process, they contain substantive requirements governing energy efficiency provisions for the building envelope, mechanical and water heating systems, lighting and additional efficiency requirements and will have the force of law in Michigan once they are promulgated. Therefore, they are not purely administrative in nature. And, even if they were, this response does not explain how they protect health, safety and welfare, how they promote any regulatory environment or how they are the least burdensome alternative.

F. The Response to Item 9 of the RIS is Misleading

Item 9 requires that LARA describe any rules that are obsolete and unnecessary and can be rescinded. In response, LARA lists twelve *administrative* portions of the current rule set which it states are unnecessary because they are outdated. However, LARA does not make changes to the remainder of the 2021 IECC or address the extensive changes, noted above, made by the change from the 2015 Code.

G. The Responses to Items 12 and 12A of the RIS are Inaccurate and Misleading; The Response to 12A also Contradicts the LARA's Response to Item 31

Item 12 requires that LARA describe how the proposed rules are necessary and suitable to accomplish their purpose, in relationship to the burden(s) the rules places on individuals. *Burdens may include fiscal or administrative burdens on the individual,* or duplicative acts.

Once again, LARA's answer is, at best, non-responsive – stating that the proposed rules are administrative in nature and the proposed rules will bring the administrative application of the IECC code in line with actual practices, as well as comply with the CCA. This statement, however, is also untrue. As explained in the analysis of LARA's response to Item 3, the proposed rules violate the cost-effective provisions of the CCA.

First, in its response to Item 12, LARA seems to indicate that the current practice of Michigan's builders, remodelers, contractor and DIYers, is to follow and build to an unpromulgated, unadopted energy efficiency code, the 2021 IECC. To the contrary, *the "actual practice" in Michigan is to follow the current energy efficiency rules in effect in Michigan*.

Next, LARA reports that the adoption of the 2021 IECC will place "*no administrative burden on the individual.*" This is grossly inaccurate. Leaving aside the increased testing, reporting, certification, and signage burdens contained in the 2021 IECC, the new code would also place a large fiscal burden on individuals. The cost-effectiveness studies discussed above give a range of increased costs in the thousands of dollars to comply with the 2021 IECC. The two studies specific to Michigan (PNNL Study and ConSol Impact Study) have an average cost of compliance for a one-story house of:

- $5,838 in Climate Zone 5,
- $3,555 in Climate Zone 6
- $5,195 in Climate Zone 7.

A two-story home has an average compliance cost of:

- $6,902 in Climate Zone 5,
- $3,535 in Climate Zone 6
- $5,195 in Climate Zone 7.

These constitute substantial burdens on individuals which the RIS fails to mention.

Further, a study completed by the Housing Economics Department of the National Association of Home Builders determined that, in 2021, every $1,000 increase in the price of a new home priced 5,297 Michigan families out of the market for a new home. See, NAHB Study, Exhibit 8. This constitutes a significant amount of potential new homebuyers. And, the NAHB Study was conducted before the Federal Reserve increased interest rates and placed these homes further out of reach to lower- and mid-income families. Therefore, the current fiscal impact of the proposed rules will be even larger.

LARA's response also ignores the additional construction costs found by each of the studies discussed above, stating, incorrectly, that any additional material and construction costs incurred by the promulgation of these rules would be due to "*an increased cost due to inflationary expenses for material costs in new build structures or renovations*." This assertion is wholly unsupported. And, again, despite the inclusion of the phrase "*cost-benefit analysis*" in the

RIS title, LARA has failed to show any verifiable data, study, or analysis of compliance with the law and the cost-effectiveness standards of the CCA. See also, response to Item 28 for further elaboration on LARA's failure to comply with these requirements.

Item 12A requires that LARA identify how the requirements in the rules are still needed and necessary. LARA, however, makes no such identification. It provides no explanation why, in the face of the increased administrative and fiscal burdens, the requirements in the rules are still needed and necessary. Instead, it makes the erroneous statement that the amendments, with all of their new and complex requirements including newly required testing, reports, expansion of mandatory provisions, new material requirements and the need to determine which one of five compulsory additional efficiency options to use, will "*make compliance less burdensome.*" This statement is plainly not credible.

Additionally, adopting a more costly, multifaceted and confusing set of energy efficiency rules under which, according to LARA, the individual **"*may*** *realize a net savings in energy costs pursuant to these requirements*," is a further indication these proposed rules will create administrative and fiscal burdens on individuals and businesses. LARA cannot definitively state, as a matter of fact, that ANY cost savings WILL occur. The studies demonstrate, instead, that the 2021 IECC cannot met the standards for cost-effectiveness.[11]

H. The Response to Item 17 of the RIS Contradicts the Department's Response to Item 31

Item 17 asks LARA if the proposed rules have any impact on the environment? If yes, please explain.

[11] This response also contradicts LARA's response to Item 31 where its states that owners of new built structures and renovations will see both "*energy savings*" and "*long-term cost savings*."

LARA's response is, "*unknown*." Further, LARA admits that it "*does not have the scientific knowledge to determine what may or may not impact the environment.*" By contrast, LARA's response to Item 31 provides that a "*primary and direct benefit of our proposed rules include … a reduction in the carbon footprint.*"

Which is it? In one response LARA states that it does not have the scientific knowledge to determine what may or may not impact the environment, while in another it claims a primary and direct benefit of the rules will be the environmental impact of a reduced carbon footprint. <u>See</u>, Item 31 for a more in-depth analysis of LARA's conflicting response to that Item.

I. The Response to Item 21 of the RIS is Incorrect

Item 21 requires that LARA identify the nature of any report and the estimated cost of its preparation by small businesses required to comply with the proposed rules. In response, LARA initially indicates that it had not received any reports regarding the estimated costs to small businesses. The statement that no reports were received appears accurate, according to Freedom of Information Act requests to LARA.

However, the response continues: "*[t]here are no anticipated reports or increased costs to small businesses that are required to comply with the proposed rules.*" This statement is incorrect on its face. Many small businesses involved with construction would be required to comply with the proposed rules. The proposed rules contain substantive requirements governing energy efficiency provisions for the building envelope, mechanical and water heating systems, lighting and additional efficiency requirements. Many of these provisions require new testing, certification and reports for compliance. These reports will often be performed by for-profit third parties – at additional costs to small construction businesses. Promulgation of this proposed rule set <u>would</u> increase reporting requirements and costs to small businesses.

J. The Responses to Item 28 is Inaccurate and Misleading

Item 28 asks for an estimate of the statewide compliance costs of the rule amendments on businesses and groups. LARA responds that it is unable to estimate compliance costs "*due to many variables.*" Simply put, LARA fails to even try to calculate an estimate.

Since the adoption of the CCA in 1999, cost-benefit analyses have been done for each new set of energy efficiency rules. These analyses are conducted using two model homes, a one-story and a two-story house, usually provided by the BCC. The analyses are done for each of Michigan's three climate zones. The results of these analyses have not only been used to determine compliance with the CCA's cost-effectiveness requirements but also used to estimate the statewide cost of compliance.

Assuming 13,000 new single-family homes (the number of homes built in 2021) were constructed under the proposed rules, at a compliance cost of $5,181 (which is the average compliance cost for both model homes used in the PNNL Study and the ConSol Impact Study in all three climate zones), a reasonable statewide estimate of the increased costs of construction for new homes in Michigan caused by compliance with the new code would be **$67,353,000.** That total includes only single-family homes and does not include any other residential construction. And, that total is only for one year of home construction.

Further, by law, every builder and remodeler licensee must have a copy of the newest code book. Michigan has approximately 40,000 individual licensees. There are also approximately 200 building departments which will need copies. At the current price of the 2021 IECC (excluding volume discounts), the total purchase price of the required copies of the IECC will be approximately $2,412,000. All of this revenue goes to the private business that created these codes and are the sole source for these publications.

K. The Response to Item 28A of the RIS is Erroneous

Item 28A requires that LARA identify the business or groups who will be directly affected by, bear the cost of, or directly benefit from the proposed rules. LARA's response to Item 28A makes clear a major flaw found throughout the RIS, namely its description of "*who bears the cost of the new standards.*" LARA states, "*The individuals who will build a new structure or renovate an existing structure will bear the costs of the new standards.*"

<u>This is erroneous</u>. **<u>The cost of complying with these new standards will ultimately be paid for by Michigan families seeking to purchase a new home. That is the foundation, the purpose and the reason for the CCA's cost-effectiveness standards</u>**.

L. The Response to Item 29A of the RIS is Incomplete

Item 29A requires that LARA state how many and what categories of individuals will be affected by the rules. The response from LARA is: skilled trade licensees and other regulated individuals (architects, engineers) will be affected.

First, LARA omits the obvious – builders and maintenance and alteration contractors, who are licensed under the Occupational Code and thus do not possess licenses under the Skilled Trades Act. More importantly, however, **<u>LARA omits the largest and most important category of individuals who would be affected by these rules – Michigan families looking to buy a new home</u>.**

M. The Response to Item 29B of the RIS is Erroneous and Incomplete

Item 29B requires that LARA state the qualitative and quantitative impact the proposed changes in rules have on individuals identified in response to Item 29A. LARA responds initially the quantitative impact will "*be unknown*" as the agency is unable to estimate costs due to the many variables which are at the discretion of the individual. In other words, the analysis is complex.

This is not true. As shown in the analysis of LARA's response to Item 28, an estimate of the potential impact of the rules to satisfy the requirement is actually arrived at fairly easily. But, instead of doing the analysis, LARA simply ignored all of the following information that was provided to it or that it already had in its own records:

1. Documentation on the negative effects of the proposed rules on the ability of Michigan families to purchase a new home because of:

- mortgage rate increases by 25 basis points increments
- home price increases by $1,000 increments
- price increases by Metropolitan Statistical Areas (MSAs).

2. A "*housing affordability pyramid*" showing the number of Michigan households (in thousands) by the highest priced home they can afford based on income.

3. The number of builders and Maintenance and Alteration Contractors licensed in Michigan as well as the number of local building departments which it has at its fingertips through the BCC.

Next, LARA states in response to Item 29B, that the qualitative impact is that the rules would result in a cost savings "… *in the long run*." This statement illustrates, directly, the reason the Michigan Legislature repealed the CABO Model Energy Code and required a new energy code with the statutory mandate that it be "cost-effective" as defined by the Legislature. Specifically, **the Michigan Legislature did not want home buyers to pay for proposed energy efficiency standards and requirements that did not return their costs in energy savings within a 7-year period or which priced them out of the market for a home.** This response to Item 29B, "in the long run," is exactly what the Legislature was trying to prevent.

A more realistic view of the qualitative impact of the proposed rules would be:

1. Builders and remodelers will include the thousands of dollars of compliance costs in the price of each home, driving up the costs of housing and further reducing the number of Michigan families who can purchase that home.

2. Renovating an existing structure will also become more expensive under the proposed rules, again affecting the ability of families to repair and improve their homes.

3. The price of existing homes will rise as well. While there is no linear correlation between the price of a newly-constructed home and one already in existence, increases in existing home prices often reflect the increase in the price of new homes.

4. Rents will continue to increase.

According to Redfin, a full-service real estate brokerage serving the United States and portions of Canada, the average rent in Detroit is now $1674, a 13.69 per cent increase in rental costs over the last year. The increased cost of renting makes it harder for Michigan families to save for new homes. Further, Daryl Fairweather, chief economist for Redfin, told National Public Radio, "After the last housing crash, not enough homes were built for a decade. That lack of supply is the biggest force pushing up home prices and making it harder for people to afford to buy and rent homes and apartments." In short, the result of the adoption of the proposed rules will be that housing at all levels will become less obtainable.

N. The Response to Item 30 of the RIS is Erroneous, Evasive and Revealing

Item 30 requires that LARA quantify any cost reductions to businesses, individuals, groups of individuals, or governmental units as a result of the new rules. LARA answers that "*[t]he cost reductions will depend on if the businesses, individuals, groups of individuals, or governmental units build a new structure or renovate new structure in which they are located. If the* *aforementioned groups* ***stay within their existing building, and never make any changes to said building, they will neither incur costs*** *nor realize savings based on this new set of rules."*

Simply put, LARA admits in its response to Item 30, it cannot point to any quantifiable cost reductions which are a result of these proposed rules – not even the professed energy savings. Therefore, **the only way to avoid incurring the thousands of dollars in additional costs required by the proposed rules is to not build or remodel anything.**

O. The Response to Item 31 of the RIS is Vague, Unverified and Fails to Provide the Requested Information

Item 31 requires that LARA estimate the primary and direct benefits and any secondary or indirect benefits of the proposed rules. It asks LARA to provide both quantitative and qualitative information, as well as their assumptions. LARA's response, however, contains no quantitative information.

LARA does not explain how or why the proposed rules will provide "*long-term cost savings,"* or any verifiable measure of those cost savings. LARA does not explain how or why the proposed rules will result in "*a reduction in the carbon footprint of … new build structures and renovations"* or any verifiable measure of those reductions. In fact, LARA contradicts its earlier response in Item 17 in which it states that any impact of these rules on the environment is, "*unknown;"* and that LARA "*does not have the scientific knowledge to determine what may or may not impact the environment."*

LARA's response does not explain how or why the proposed rules will provide "*energy savings to the owners of new built structures and renovations*" or any verifiable measure of those cost savings. Instead, LARA professes that secondary and indirect benefit of the proposed rules will accrue to "*the skilled trade professionals who will benefit from the contracted work (*which*) will result from an updated energy code"* without any explanation how the contracted work resulting from an updated energy code will differ from the work contracted for under the current energy code.

In short, LARA's response to Item 31 contains no quantitative or qualitative information as required. LARA's response contains only a series of unsupported assumptions.

P. The Response to Item 32 of the RIS is Imprecise and Incomplete

Item 32 requires LARA to explain how the proposed rules will impact business growth and job creation (or elimination) in Michigan. LARA's unsubstantiated response is that the proposed rules will benefit the skilled trades professions as well as the energy related industry due to the new requirements which are established in the proposed rule set. Simply put, aside from this contention, LARA has provided no information on how or why these rules will benefit these parties or how it will impact business growth and job creation or elimination in Michigan as opposed to the effects of the current energy code.

Q. The Response to Item 33 of the RIS is Revealing

Item 33 requires that LARA identify any individuals or businesses who will be disproportionally affected by the rules as a result of their industrial sector, segment of the public, business size or geographic location. LARA's response is, "*There may be some individuals or businesses which will not build a new structure or renovate an existing structure because they do not wish to implement the new energy code standards.*"

This response is not plausible. In fact, it is highly improbable that someone will not build a new or renovate an existing structure for the sole reason that "*<u>they do not wish</u> to implement the new energy code standards.*" Rather, it is much more plausible that an inability to financially afford the thousands of dollars in identified additional costs of compliance with the new energy code standards is behind the decision to not build.

R. The Response to Item 34 of the RIS is Equally as Revealing

Item 34 requires that LARA identify the sources the agency relied upon in compiling the RIS, including the methodology utilized in determining the existence and extent of the impact of the proposed rules and a cost-benefit analysis of the proposed rules. LARA's response includes a list of various boards, commissions, and stakeholders as well as the comments from the Code/Rule Proposal forms in the 3-day public advisory meeting considered when formulating the RIS for this rule set. The response also states LARA received several cost-benefits analyses during this process.

Despite all of the data, information, and advice LARA received, the RIS for this proposed rule set does not contain a single quantifiable statement concerning the increased construction costs which would result from the adoption of these rules or its impact on potential home buyers. The RIS is devoid of any quantifiable, verifiable cost-benefit analysis as required by the CCA and the APA. LARA received at least four independent studies conducted by four different reputable energy consulting organizations, all of which established that the 2021 IECC did not meet the 7-year cost-effective requirement of the CCA. This data is found nowhere in the RIS.

S. The Response to Item 34A of the RIS is Nonresponsive

Item 34A requires that LARA report on how the estimates were made and identify its assumptions. It requires LARA to include internal and external sources, published reports, information provided by associations or organizations, etc., that demonstrate a need for the proposed rules. LARA's response provides none of the required items, yet these items are critically important to evaluating the proposed rules.

This proposed rule set followed a new implementation process which lacks the openness and transparency of past practice, as described in more detail below. As a result, the need for accurate and comprehensive answers to the RIS is critical to determine the appropriateness of these proposed changes for Michigan's families.

Beginning with the adoption of the CABO MEC in 1994, LARA used broad-based and balanced review committees composed of various technical experts to review the codes as well as any proposed changes to the codes and make recommendations to the LARA director as to the contents of the updated codes. All code review committee meetings were posted and open to the public. All proposed code changes were likewise available for public scrutiny.

Proponents of code changes were offered the chance to explain their proposed changes to the committee and answer any questions the committee members might have. Opponents of proposed changes were given the same opportunity.

The committee engaged in full and open discussion and debate. The committee met on a regular schedule and hours of conversation took place. Attendees at the committee meetings were offered the opportunity for meaningful comment before any vote was taken on a proposed change by the committee.

This open exchange of information and opinion was integral to the review process. And <u>all votes of the review committees were taken in public view</u>. Thus, agree or not, all interested parties could hear the reasons for any code changes approved by the committee.

This process was one of the most open and transparent in the county and has been widely copied. This process served the state, the construction industry, and Michigan's citizens well for over 30 years. Michigan was considered to be a national leader in construction code adoption.

Despite the repeated success of this proven approach over three decades, LARA abandoned the use of these expert review committees and, in its place, instituted a

two-person review committee which works without transparency and public scrutiny. Public access to the rule-making process was severely curtailed by this decision.

Under this new, limited process, LARA accepts and posts any suggested code change. It held several hours of Public Advisory meetings spread over three days on a first draft of the rules. But, at that point, transparency and public input stopped.

Discussions, debate and decisions of the contents and requirements of the code were made by two people outside of the public eye. And, no explanation was offered for any decision made by these two individuals.

The APA required public hearing will, of course, be held. However, while the public's comments and questions will be heard at this hearing, there will be no response whatsoever from LARA. And, following the adjournment of the public hearing the decisions on the content of the new code will again be made outside the view of the public. This version of the code will then be transmitted to the director of LARA for her approval. This new process and its lack of openness and transparency make accurate and comprehensive answers to the RIS critical to determine the appropriateness of these proposed rule changes for Michigan's families.

T. The Response to Item 35 of the RIS is Disingenuous

Item 35 requires that LARA identify any reasonable alternative to the proposed rules that would achieve the same or similar goals. LARA responds that no reasonable alternatives have been identified. This raises the question, were any alternatives even looked at? The response suggests that LARA made no internal effort to identify any reasonable alternatives.

As stated in the CCA at **MCL 125.1502a(s)**, energy conservation is "*the efficient use of energy by providing building envelopes with high thermal resistance and low air leakage, and the selection of energy efficient mechanical, electrical service, and illumination systems, equipment, devices, or apparatus.*"

Also found in the CCA is **MCL 125.1504(3)(g)**, which requires the code "*to continue to seek ever-improving, cost-effective energy efficiencies*."

These, along with cost-effectiveness, under the CCA, are the stated goals of the energy code.

Nothing in the CCA limits LARA to alternatives identified by others in the code proposal process or public advisory meetings. LARA may consider reasonable options on its own.

Did LARA consider the reasonable alternative of adopting and amending Chapter 11 of the 2018 IRC?

Did LARA consider the reasonable alternative of amending the 2021 IECC to eliminate those individual requirements which do not meet the cost-effective test?

Did LARA determine that the unamended 2021 IECC meets Michigan's cost-effective standards, and if so, how?

LARA's response contains no answers to these and other questions.

U. The Response to Item 38 of the RIS is Misleading

Item 38 requires that LARA describe any instructions regarding the method of complying with the rules, if applicable. The response states: "*[t]here are no instructions regarding the method of complying with the rules*."

If one looks only at the rules set and not at the code it is promulgating, this might seem to be true. However, an examination of the actual printed code reveals page after page of new, detailed, complex, and interlocking instructions on how requirements of the code are to be complied with. The answer is wrong, but also suggests a failure to treat the RIS as worthy of serious consideration.

V. Conclusions

LARA has failed to provide complete and accurate responses to 25 of the 38 items required on the Regulatory Impact Statement and Cost-Benefit Analysis. Specifically, as examples:

1. LARA has failed to accurately assess the impact of the proposed rules on both small and large businesses.

2. LARA has failed to supply quantitative and/or qualitative data where required.

3. LARA has failed to show how the proposed rules would protect the public health, safety and welfare of Michigan citizens while promoting a regulatory environment that is the least burdensome alternative for those required to comply.

4. LARA has repeatedly stated the rules are "*administrative*" in nature when they contain hundreds of substantive requirements.

5. LARA has failed to provide any verifiable study, analysis, or report showing the proposed rules met the CCA's 7-year simple payback requirements.

6. LARA has failed to provide any verifiable study, analysis, or report showing the proposed rules meet the CCA's requirement that individuals who qualify for a mortgage before the cost of the added energy efficiency regulations will continue to qualify for a mortgage.

7. LARA has failed to provide any and verifiable study, analysis, or report showing the proposed rules meet the CCA's requirement the costs of principal, interest, taxes insurance, and utilities will not be greater after the inclusion of the proposed energy efficiency rules than they were before.

8. LARA has failed to identify the statewide compliance costs of the proposed rules.

9. LARA has failed to recognize and report on the fiscal and administrative burdens on individuals.

10. LARA has given contradictory responses on the effect of the proposed rules on the environment.

11. LARA has erroneously claimed there were "*no anticipated reports or increased costs to small businesses"* (builders, remodelers, DIYers and skilled trades) that are required to comply with the proposed rules.

12. LARA has failed to account for the effects of the proposed rules on Michigan families seeking to purchases a home.

13. LARA has failed to produce evidence of any quantifiable savings from the proposed rules.

14. LARA has failed to specify the costs and benefits arising from the new rules.

15. LARA has failed to identify the behavior and the frequency of behavior the proposed rules are designed to alter.

In sum, the statutorily-required RIS submitted by LARA is deficient, does not meet the requirements of the APA and does not justify the adoption of the proposed rules. Having failed to comply with Michigan law in the adoption process, the adoption should not move forward.

VII. Reservation of Rights

In May 2002, HBAM served a number of requests for documents on various State agencies relating to the currently proposed amendments. The following responses remain outstanding:

Date Submitted	Payments Requested & Submitted	Recipient	Documents Requested
5/4/22	Deposit: 5/25/22 invoiced 5/26/22 paid Balance: 6/21/22 invoiced 6/21/22 paid	LARA	"all documents, including correspondence, contracts, reports, studies, minutes, and all electronic records, including email, from June 15, 2021, to present which refer, relate and/or constitute correspondence between any employee or representative of the MDNR and/or the BCC, regarding adding, amending, rescinding rules to update any of the following:

Date Submitted	Payments Requested & Submitted	Recipient	Documents Requested
			-Michigan Energy Code -International Energy Conservation Code”
5/16/22	<u>Deposit</u>: 6/8/22 invoiced 6/9/22 paid	LARA	“all documents, including correspondence, contracts, reports, studies, minutes, and all electronic records, including email, from June 15, 2021, to present which refer, relate and/or constitute an analysis, study or determination as to whether the 2021 International Energy Conservation Code is “cost-effective” as defined in MCL 125.1502a(p).”
5/6/22	<u>Deposit</u>: 5/25/22 invoiced 5/25/22 paid	EGLE	“all documents, including correspondence, contracts, reports, studies, minutes, and all electronic records, including email, from June 15, 2021, to present which refer, relate and/or constitute correspondence between any employee or representative of the MDEGLE and/or [the Office of Climate and Energy, Council on Climate Solutions, Office of Environmental Justice Public Advocate, and Office of Legislative Affairs], regarding adding, amending, rescinding rules to update any of the following: -Michigan Energy Code -International Energy Conservation Code”

Under the Freedom of Information Act (“FOIA”), a public body responding to a FOIA Request must, within 5 business days:

(a) Grant the request.

(b) Issue a written notice to the requesting person denying the request.

(c) Grant the request in part and issue a written notice to the requesting person denying the request in part.

(d) Issue a notice extending for not more than 10 business days the period during which the public body shall respond to the request. A public body shall not issue more than 1 notice of extension for a particular request.

MCL 15.235(2). Here, both LARA and EGLE issued notices extending their respective response times by 10 business days. Thereafter, LARA and EGLE requested deposits pursuant to

MCL 15.234(8) which HBAM paid within 1 day after the date(s) invoiced. On May 25, 2022, EGLE granted the May 6, 2022 Request and acknowledged receipt of the deposit requested, but no balance due has been requested and no documents have been provided to date. On June 21, 2022, LARA confirmed receipt of payment of the balance owed on the May 4, 2022 Request but has still not produced the responsive documents. On June 8, 2022, LARA granted the May 16, 2022 Request but granted itself an additional 30 business days "best efforts estimate" to respond, pursuant to MCL 15.234(8), which provides:

> In either the public body's initial response or subsequent response as described under section 5(2)(d), the public body may require a good-faith deposit from the person requesting information before providing the public records to the requestor if the entire fee estimate or charge authorized under this section exceeds $50.00, based on a good-faith calculation of the total fee described in subsection (4). Subject to subsection (10), the deposit must not exceed 1/2 of the total estimated fee, and a public body's request for a deposit must include a detailed itemization as required under subsection (4). The response must also contain a best efforts estimate by the public body regarding the time frame it will take the public body to comply with the law in providing the public records to the requestor. The time frame estimate is nonbinding upon the public body, but the public body shall provide the estimate in good faith and strive to be reasonably accurate and to provide the public records in a manner based on this state's public policy under section 1 and the nature of the request in the particular instance. If a public body does not respond in a timely manner as described under section 5(2), it is not relieved from its requirements to provide proper fee calculations and time frame estimates in any tardy responses. Providing an estimated time frame does not relieve a public body from any of the other requirements of this act.

MCL 15.234(8).

> A public body's "best efforts estimate" under subsection 4(8) of FOIA, as to the time it will take to fulfill a request for public records, must be a calculation that contemplates the public body working diligently to fulfill its obligation to produce the records to the requestor. The estimate must be comparable to what a reasonable person in the same circumstances as the public body would provide for fulfilling a similar public records request. In addition,

> under subsection 4(8), the best efforts estimate must be made in "good faith," that is, it must be made honestly and without the intention to defraud or delay the requestor.

2017 Mich OAG No. 7300, *4 (December 12, 2017); 2017 WL 6409351. LARA has not demonstrated that it is using "best efforts" to respond to the May 16, 2022 FOIA Request. And, neither LARA nor EGLE have proffered any excuse for continuing to withhold the documents requested in the May 4, 2022 and May 16, 2022 FOIA Requests.

The delays in responding to FOIA Requests that have been granted and paid for is contrary to the FOIA. Accordingly, due to the unwarranted delays of LARA and EGLE in responding to HBAM's FOIAs, HBAM reserves the right to amend this Position Statement to discuss any issues or claims raised by the documents that are eventually produced.[12]

S:\docs\1000\C1029\M128\Position Statement 070122.docx

[12] Update – Documents which LARA claims are responsive to the May 4, 2022 FOIA Request were made available on June 29, 2022. Due to the large volume of documents and the minimal time given to review them prior to filing this Position Statement, HBAM continues its reservation of rights with respect to the May 4, 2022 FOIA Request.

Exhibits to the Position Statement

1. Lee Schwartz CV
2. Residential Code Notice
3. PNNL Study
4. HIRL Study
5. ICF Study
6. RMI Study
7. ConSol Impact Study
8. NAHB Study
9. NAHB Study #2
10. June 9, 2022 Regulatory Impact Statement

EXHIBIT 1

Lee Schwartz
Cayalyst Consulting, LLC

Curriculum Vitae

International Code Council Member 1999 - Present

Code Officials Conference of Michigan Member 2010-2021

St. Louis, MO	1999	Baltimore, MA	2009
Portland, OR	2001	Dallas, TX	2010
Pittsburgh, PA	2002	Dallas, TX	2013
Fort Worth, TX	2002	Atlantic City, NJ	2013
Nashville, TN	2003	Louisville, KY	2016
Overland Park, KS	2003	Kansas City, MO	2016
Cincinnati, OH	2005	Columbus, Ohio	2018
Detroit, Ml	2005	Albuquerque, NM	2018
Lake Buena Vista, FL	2006	Richmond, VA	2018
Rochester, NY	2007	Albuquerque, NM	2019
Palm Springs, CA	2008	Clark County, NV	2019
Minneapolis, MN	2008	Rochester, NY	2022

ENERGY CODE ACTIVITIES

ICC Group B IECC-R/IRC-E Code Committee Appointed Member 2024

ICC Group B IECC-R/IRC-E Code Committee Member 2021

Michigan Residential Code Chapter 11 Negotiations Group Member 2012-2013

Michigan Energy Code Review Committee Participating Observer 1999, 2002, 2005, 2008, 2011

Ad Hoc Michigan Uniform Energy Code Committee Member 1995-1996

OTHER CONSTRUCTION CODE RELATED ACTIVITIES

Residential Builder Continuing Competency Instructor 2008 - Present

State Construction Code Commission Participating Observer 1991-2021

Department of Labor and Economic Opportunity's Home Services Providers Return to Work Workgroup Member 2020

Michigan Residential Code Review Committee Participating Observer 1999, 2002, 2005, 2008, 2011, 2014

Building Officials and Inspectors Registration Act Rules Committee Member 1998, 2000, 2013

Governor's Inspections and Permitting Advisory Rules Committee Member 2012-2013

Michigan Electrical Code Review Committee Member 2003, 2006, 2009

OTHER GOVERNMENTAL ACTIVITIES

Department of Environment, Great Lakes and Energy Business Stakeholders Council Member 2019 - present

MIOHSA Five-year Planning Committee Stakeholder Representative 1999, 2004, 2009, 2014, 2018

Flex Code Act Lead Negotiator 2011-2012

Michigan Legislature Wetlands Advisory Council Member 2009-2012

Department of Environmental Quality ("DEQ") Critical Sand Dunes Program Review Committee Member 2007-2012

DEQ Environmental Advisory Council Member 2008-2010

Michigan Constitutional Amendment on Eminent Domain Negotiator 2006

Land Division Act Work Group Member 2003-2005

MIOSHA Asbestos Rule Committee Member 1999-2000

Single State Construction Code Act Lead Negotiator 1998-1999

DEQ On-site Septic and Water Rules Committee Member 1996-1997

Subdivision Control Act Work Group Member 1995-1996

MIOSHA Confined Space Permit Required Rule Committee Member 1995

DEQ Storm Water Permit Fee Committee Member 1994-1995

EXHIBIT 2

Melissa Hagen

From:	Michigan Department of Licensing and Regulatory Affairs <LARA@govsubscriptions.michigan.gov>
Sent:	Wednesday, June 15, 2022 1:14 PM
To:	Melissa Hagen
Subject:	2021 Part 5 Residential Code

LARA
LICENSING AND REGULATORY AFFAIRS

CONSTRUCTION CODES

Residential Code

The 2021 Residential rules are now open, and we are seeking your input.

For your convenience, a Proposal Rule/Code Change Request form is attached. The current Residential rule set can be reviewed under our Administrative Rules webpage. Proposals for this rule set must be submitted toLARA-BCC-Rules@michigan.gov by 5:00 p.m. on Friday, July 15, 2022. Status of the rule set progression will be posted on our website.

To be included in our email distribution list and stay updated on rule set information, please send an email to LARA-BCC-Rules@michigan.gov with the rule set that you want to be informed on in the subject line. You will be notified of upcoming public hearings, proposed code changes, and any other relevant information.

Amanda Johnson
Rules Analyst
LARA/Bureau of Construction Codes
Administrative Services Division
P.O. Box 30254
Lansing, MI 48909
(517)582-5519 – Telephone
www.michigan.gov/bcc

- BlankCode-RuleProposalRequestForm2_682022_7.pdf

EXHIBIT 3

PNNL-31604

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

July 2021

Victor R Salcido
Yan Chen
YuLong Xie
Zachary T Taylor

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

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PNNL-31604

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

July 2021

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Pacific Northwest National Laboratory
Richland, Washington 99354

Highlights

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

Moving to the 2021 International Energy Conservation Code (IECC) is cost-effective for both single-family and low-rise multifamily residential buildings in Michigan. The 2021 IECC will provide statewide energy savings of 10.7% across all climate zones compared to the current state energy code. This equates to $ 327 of annual utility bill savings for the average Michigan household. It will reduce statewide CO_2 emissions over 30 years by 11,460,000 metric tons, equivalent to the annual CO_2 emissions of 2,493,000 cars on the road (1 MMT CO_2 = 217,480 cars driven/year). Updating the state energy code based on the 2021 IECC will also stimulate the creation of high-quality jobs across the state. Adopting the 2021 IECC in Michigan is expected to result in homes that are energy efficient, more affordable to own and operate, and based on current industry standards for health, comfort and resilience.

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

Consumer Impact

Metric	Compared to the 2015 IECC with amendments
Life-cycle cost savings of the 2021 IECC	$4,514
Net annual consumer cash flow in year 1 of the 2021 IECC[2]	$97
Annual (first year) energy cost savings of the 2021 IECC ($)[3]	$327
Annual (first year) energy cost savings of the 2021 IECC (%)[4]	10.7%

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

Statewide Impact - Emissions

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, $	3,873,000	1,251,000,000
CO_2 emission reduction, Metric tons	24,960	11,460,000
CH_4 emissions reductions, Metric tons	1.83	839
N_2O emissions reductions, Metric tons	0.255	117
NOx emissions reductions, Metric tons	17.93	8,231
SOx emissions reductions, Metric tons	15.57	7,151

Statewide Impact – Jobs Created

Statewide Impact	First Year	30 Years Cumulative
Jobs Created -- Reduction in Utility Bills	187	4851
Jobs Created -- Construction Related Activities	257	6675

Acronyms and Abbreviations

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

Contents

Figures

Tables

1.0 Cost-Effectiveness Results for the 2021 IECC for Michigan

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

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

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

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

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

1.1 Life-Cycle Cost

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

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

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

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

Climate Zone	Life-Cycle Cost Savings ($)
5A	4,480
6A	4,670
7	6,470
State Average	**4,514**

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

1.2 Consumer Cash Flow

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

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

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

	Cost/Benefit	5A	6A	7	State Average
A	Incremental down payment and other first costs	$506	$433	$624	$499
B	Annual energy savings (year one)	$338	$324	$476	$337
C	Annual mortgage increase	$175	$150	$216	$172
D	Net annual cost of mortgage interest deductions, mortgage insurance, and property taxes (year one)	$69	$59	$85	$68
E = [B-(C+D)]	Net annual cash flow savings (year one)	$94	$116	$175	$97
F = [A/E]	Years to positive savings, including up-front cost impacts	5	4	4	5

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

1.3 Simple Payback Period

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

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

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

Climate Zone	Payback Period (Years)
5A	12.0
6A	10.7
7	10.5
State Average	**11.8**

2.0 Overview of the Cost-Effectiveness Analysis Methodology

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

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

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

2.1 Estimation of Energy Usage and Savings

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

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

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

2.2 Climate Zones

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

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

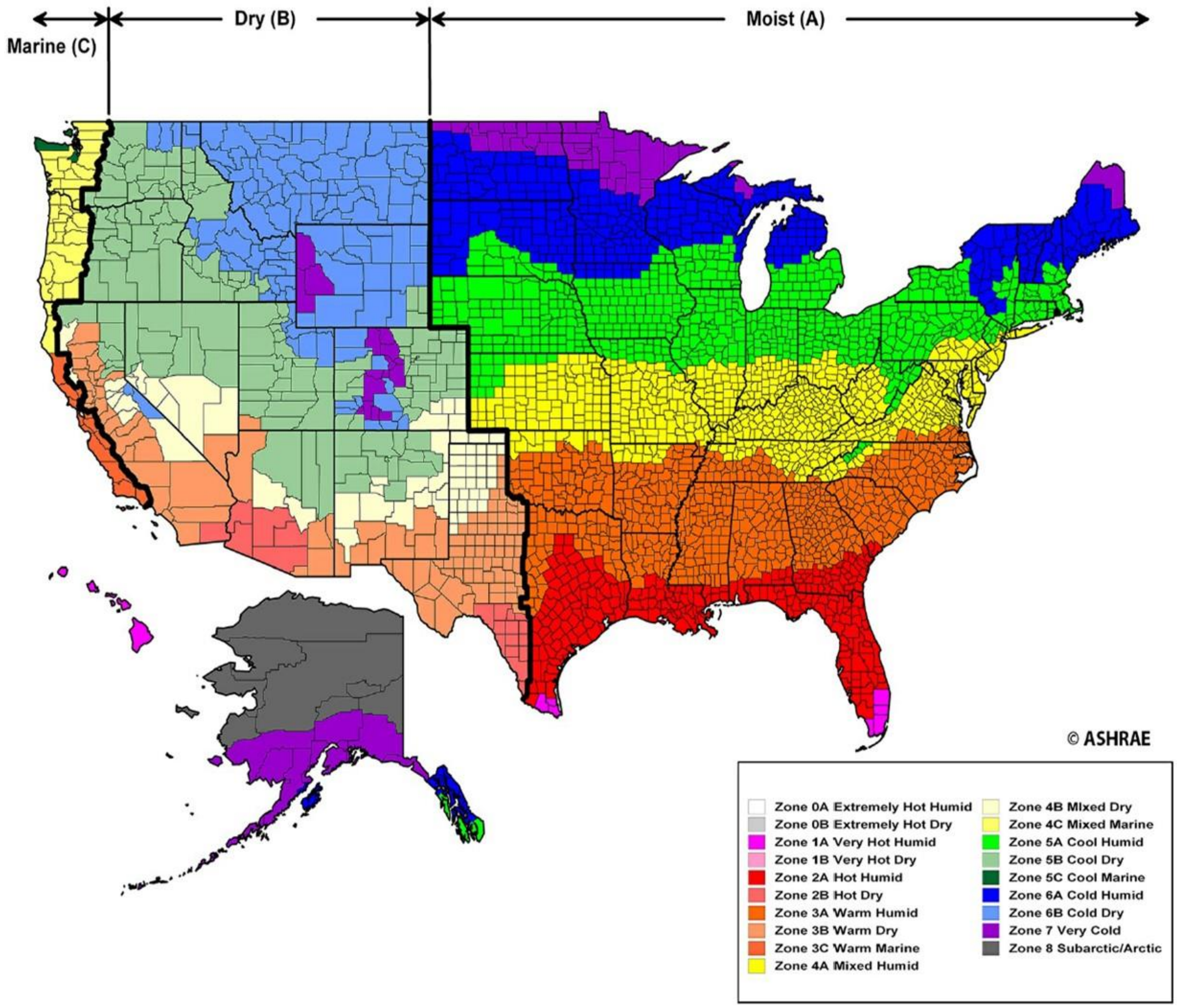

Figure 1. National Climate Zones

2.3 Fuel Prices

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

Table 4. Fuel Prices used in the Analysis

Electricity ($/kWh)	Gas ($/Therm)	Oil ($/MBtu)
0.164	0.721	2.279

2.4 Financial and Economic Parameters

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

Table 5. Economic Parameters Used in the Analysis

Parameter	Value
Mortgage interest rate (fixed rate)	3%
Loan fees	1% of mortgage amount
Loan term	30 years
Down payment	12% of home value
Nominal discount rate (equal to mortgage rate)	3%
Inflation rate	1.4%
Marginal federal income tax	12%
Marginal state income tax	4.25%
Property tax	1.62%

2.5 Aggregation Scheme

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

Table 6. Heating Equipment Shares

Heating System	Share of New Homes (percent)	
	Single-Family	Multifamily
Natural Gas	78.4	78.4
Heat Pump	20.5	20.5
Electric Resistance	0.6	0.6
Oil	0.5	0.5

Table 7. Foundation Type Shares

Foundation Type	Slab-on-grade	Heated Basement	Unheated Basement	Crawlspace
Share of New Homes (percent)	15.4	35.9	28.2	20.5

Table 8. Construction Shares by Climate Zone

Climate Zone	Share of New Homes (percent)	
	Single-Family	Multifamily
5A	81.5	18.5
6A	81.5	18.5
7	81.5	18.5

3.0 Incremental Construction Costs

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

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

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

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

Table 9 and Table 10 show the incremental construction costs associated with the 2021 IECC compared to the 2015 IECC with amendments for an individual dwelling unit. Table 9 shows results for a house and Table 10 shows results for an apartment or condominium. These have been adjusted using a construction cost multiplier, 0.989, to reflect local construction costs based on location factors provided by RSMeans (2020).

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

Single-family Prototype House				
Climate Zone	**Crawlspace**	**Heated Basement**	**Slab**	**Unheated Basement**
5A	$4,116	$4,787	$4,624	$4,116
6A	$3,780	$3,780	$3,780	$3,780
7	$5,264	$5,264	$5,264	$5,264

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

Multifamily Prototype Apartment/Condo				
Climate Zone	**Crawlspace**	**Heated Basement**	**Slab**	**Unheated Basement**
5A	$1,645	$1,744	$1,720	$1,645
6A	$1,523	$1,523	$1,523	$1,523
7	$3,006	$3,006	$3,006	$3,006

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

4.0 Energy Cost Savings

2015 IECC with amendments

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

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

Climate Zone	2015 IECC with amendments						
	Heating	Cooling	Water Heating	Lighting	Fans	Vents	Total
5A	$894	$229	$220	$252	$183	$59	$3,055
6A	$1,007	$166	$233	$252	$177	$59	$3,112
7	$1,163	$118	$244	$252	$161	$59	$3,215
State Average	**$908**	**$222**	**$221**	**$252**	**$182**	**$59**	**$3,062**

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

Climate Zone	2021 IECC						
	Heating	Cooling	Water Heating	Lighting	Fans	Vents	Total
5A	$793	$201	$105	$220	$161	$29	$2,727
6A	$915	$144	$113	$220	$158	$29	$2,797
7	$882	$115	$120	$220	$131	$69	$2,753
State Average	**$806**	**$194**	**$106**	**$220**	**$160**	**$30**	**$2,735**

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

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

Climate Zone	First Year Energy Cost Savings	First Year Energy Cost Savings (percent)
5A	$328	10.7%
6A	$315	10.1%
7	$462	14.4%
State Average	**$327**	**10.7%**

5.0 Societal Benefits

5.1 Benefits of Energy Codes

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

5.2 Greenhouse Gas Emissions

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

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

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

[1] Architecture 2030

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

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

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

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

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

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

GHG	Electricity lb/MWh	Natural Gas (lb/mmcf)	Fuel Oil (lb/1000 gal)
CO_2	1,839	120,000	23,000
SO_2	1.610	0.6	12
NO_X	1.261	96	19
N_2O	0.032	0.23	0.45
CH_4	0.183	2.3	0.7

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

Table 15. Societal Benefits of the 2021 IECC

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, $	3,873,000	1,251,000,000
CO_2 emission reduction, Metric tons	24,960	11,460,000
CH_4 emissions reductions, Metric tons	1.83	839
N_2O emissions reductions, Metric tons	0.255	117
NOx emissions reductions, Metric tons	17.93	8,231
SOx emissions reductions, Metric tons	15.57	7,151

5.3 Jobs Creation through Energy Efficiency

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

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

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

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

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

Table 16. Jobs Created from the 2021 IECC

Statewide Impact	First Year	30 Years Cumulative
Jobs Created -- Reduction in Utility Bills	187	4851
Jobs Created -- Construction Related Activities	257	6675

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EXHIBIT 4

Home Innovation
RESEARCH LABS™

2021 IECC Residential Cost Effectiveness Analysis

Prepared For

National Association of Home Builders

June 2021

Report No. CR1391_06112021

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ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

AC	Air Conditioner
AFUE	Annual Fuel Utilization Efficiency
c.i.	Continuous Insulation
COP	Coefficient of Performance
CZ	Climate Zone
EA	Each
EF	Energy Factor
ERI	Energy Rating Index
GF	Gas Furnace
HP	Heat Pump
HPWH	Heat Pump Water Heater
HSPF	Heating Seasonal Performance Factor
IECC	International Energy Conservation Code
IRC	International Residential Code
LF	Linear Feet
O&P	Overhead and Profit
SEER	Seasonal Energy Efficiency Ratio
SF	Square Feet
UEF	Uniform Energy Factor
WH	Water Heater

BACKGROUND

The 2021 International Energy Conservation Code (IECC) includes several changes which impact both energy savings and construction costs for residential construction.

The objective of this analysis is to quantify the incremental construction cost and energy use cost savings associated with constructing a house compliant with the 2021 IECC relative to a 2018 IECC baseline and to evaluate the cost-effectiveness of the code changes.

METHODOLOGY

To evaluate the cost effectiveness of the 2021 IECC changes, Home Innovation Research Labs (Home Innovation) determined incremental construction costs and energy use costs using a Standard Reference House with multiple configurations and in multiple locations, constructed in accordance with the prescriptive compliance requirements of the 2018 IECC and 2021 IECC Residential Provisions ("Sections R401 through R404" in the 2018 IECC; "Prescriptive Compliance Option" in the 2021 IECC). The results provided a basis for estimating energy use savings and simple paybacks.

The analysis for this study is based on a methodology[1] developed by Home Innovation (formerly NAHB Research Center) to calculate energy savings. This methodology defined a Standard Reference House, including the building configuration and energy performance parameters, that was originally used to report an analysis of the 2012 IECC code changes[2].

For analysis in this report, annual energy use costs were developed using BEopt[3] 2.8.0.0 hourly simulation software and energy prices from the U.S. Energy Information Agency[4]. The energy prices are national average annual 2019 residential prices: $0.1301/kWh for electricity; $1.051/therm for natural gas.

Construction costs were developed based on RSMeans[5] 2021 Residential Cost Data. Costs for mechanical equipment were sourced from distributor web sites. Costs associated with testing or documentation provided by an energy rater were estimated based on an internet search of fees on rater web sites. Cost details are provided for individual code changes in Appendix A and by climate zone in Appendix B.

Appendix A costs are reported as both total to the builder and total to consumer. The total cost to builder includes overhead and profit (designated in the tables as "w/O&P") applied to individual component costs (materials and labor) to represent the cost charged by the sub-contractor. The total cost to consumer is based on applying a builder's gross profit margin of 19.0% to the builder's total cost[6]. These represent national average costs. For specific locations, the Appendix A costs could be

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[1] Methodology for Calculating Energy Use in Residential Buildings. NAHB Research Center, May 2012.

[2] 2012 IECC Cost Effectiveness Analysis. NAHB Research Center, May 24, 2012.

[3] BEopt (Building Energy Optimization Tool) software: https://beopt.nrel.gov/home

[4] Energy Information Agency: https://www.eia.gov/

[5] RSMeans, https://www.rsmeans.com/

[6] Industry average gross profit margin for 2017, as reported in NAHB's Builder's Cost of Doing Business Study, 2019 Edition. https://eyeonhousing.org/2019/03/builders-profit-margins-continue-to-slowly-increase/?_ga=2.73913042.1310550892.1620653840-1896975365.1593698293

modified by applying the appropriate location adjustment factor from RSMeans; selected location adjustment factors from RSMeans are listed in Appendix C.

Standard Reference House

The building geometry (Figure 1) used in this analysis is documented in the methodology paper and was originally developed using Home Innovation's 2009 Annual Builder Practices Survey (ABPS) for a representative single-family detached home. The parameters represent the average values from the ABPS for building areas and features not dictated by the IECC. The geometry has been updated based on Home Innovation's 2019 ABPS. Table 1 shows the floor, attic, wall, and window areas used in the Standard Reference House for this study.

Table 1. Average Wall and Floor Areas of the Reference House

Reference House Component	Area (SF)
1st floor conditioned floor area (CFA)	1,875
2nd floor CFA	625
Total CFA without conditioned basement	2,500
Foundation perimeter, linear feet (LF)	200 LF
Slab/basement/crawl floor area	1,875
Total CFA with conditioned basement	4,375
Ceiling area adjacent to vented attic	1,875
1st floor gross wall area (9' height)	1,800
2nd floor gross wall area (8.75' height)	875
Total above grade wall area (excludes rim areas)	2,675
Basement wall area (8' height; 2' above grade)	1,600
Crawlspace wall area (4' height; 2' above grade)	800
Window area (15% of CFA above grade)	375

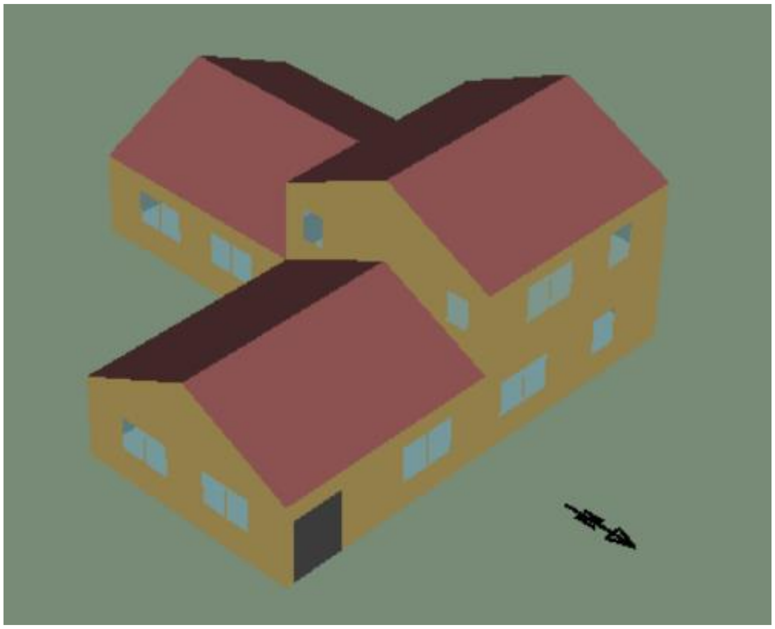


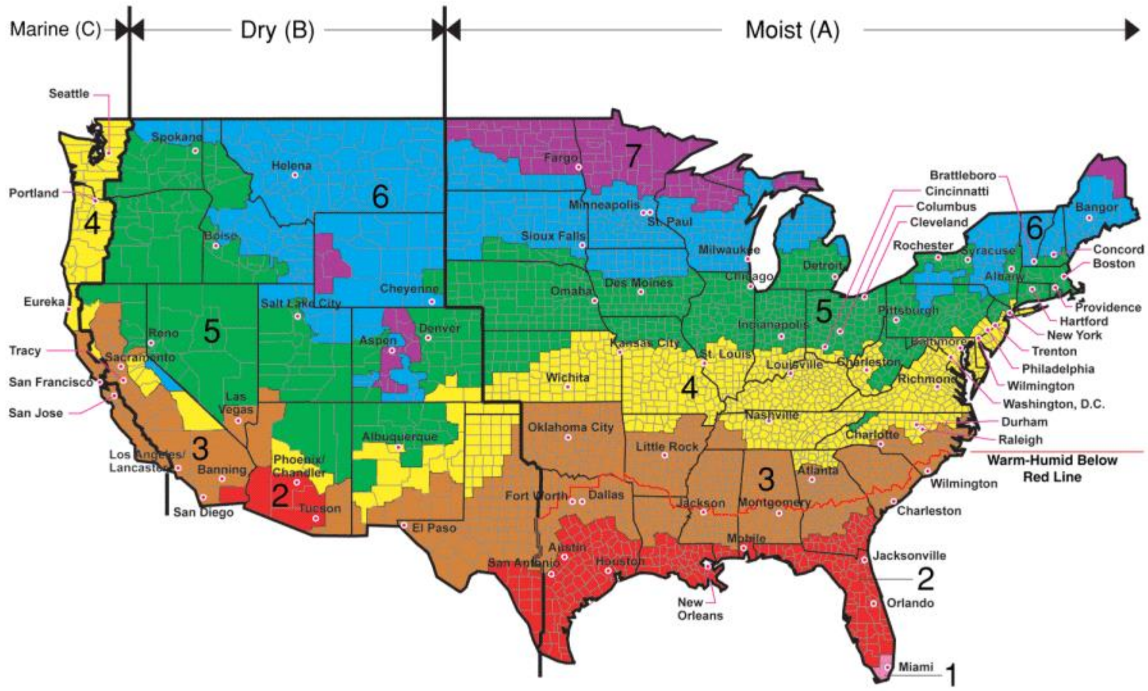
Figure 1. Simulation Model of Standard Reference House

Representative Locations

Six cities (Table 2) representing DOE Climate Zones 2 through 7 (Figure 2) were selected to quantify energy savings for their respective climates.

Table 2. Representative Locations

Climate Zone	2	3	4	5	6	7
City	Phoenix	Memphis	Baltimore	Chicago	Helena	Duluth
State	Arizona	Tennessee	Maryland	Illinois	Montana	Minnesota
Moisture Region	Dry	Moist	Moist	Moist	Dry	N/A
HDD65*	1,050	2,960	4,600	6,330	7,660	9,570
CDD65*	4,640	2,110	1,233	842	317	162
*Daily Average Weather Data (TMY). Source: Residential Energy Dynamics, redcalc.com						



All of Alaska in Zone 7 except for the following Boroughs in Zone 8: Bethel, Dellingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

Zone 1 includes: Hawaii, Guam, Puerto Rico, and the Virgin Islands

Figure 2. DOE Climate Zone Map

Configurations and Weighted Averaging

Weighted averaging was applied both within and across climate zones based on market statistics for new single-family detached homes as reported by the 2019 ABPS. Within climate zones, weight factors were applied for wall types (light-framed and mass walls) and foundation types (slab, basement, and crawlspace).

The heating fuel used for this analysis, either natural gas or electric, was selected based on the predominant heating fuel in each climate. The predominant fuel for heating is also used for domestic hot water. All other appliances are electric.

Once the costs within a climate zone were determined, a weighted calculation according to housing starts for each climate zone was performed to obtain a national average across climate zones. Weighting averages used for this analysis are shown in Table 3.

Table 3. Construction Data. Source: adapted from Home Innovation's 2019 ABPS

	CZ 2	**CZ 3**	**CZ 4**	**CZ 5**	**CZ 6**	**CZ 7**
Component	**Phoenix**	**Memphis**	**Baltimore**	**Chicago**	**Helena**	**Duluth**
Primary heating fuel	Electric	Electric	Nat Gas	Nat Gas	Nat Gas	Nat Gas
Mass Wall	30%	10%				
Frame Wall	70%	90%	100%	100%	100%	100%
Slab Foundation	100%	75%	20%	15%	5%	30%
Basement Foundation, finished		10%	60%	70%	90%	5%
Crawlspace, vented		15%	20%			
Crawlspace, conditioned				15%	5%	65%
Housing Starts	28%	28%	21%	17%	5%	1%

HVAC and Water Heating Equipment

The Reference Houses utilize federal minimum efficiency HVAC systems and water heaters as shown in Table 4, except where the 2021 IECC houses are evaluated separately with higher efficiency equipment options suitable for the climate as shown in Table 5.

High efficiency HVAC systems for electric houses consist of air-source heat pump systems (i.e., not ground source or geothermal systems) with variable speed compressors ("inverter" drive compressors that provide variable refrigerant flow). The inverter systems are generally required to meet the minimum HSPF requirement for the heat pump efficiency option for 2021 (10 HSPF/16 SEER; see next section for description of 2021 efficiency package options). In addition to higher efficiencies, inverter systems are considered more suitable for colder climates because these can ramp up to provide higher heating capacities at lower outdoor temperatures compared to typical single-stage or two-stage equipment.

High efficiency water heaters for electric houses consist of heat pump water heater, 50 gallon capacity, 2.0 EF[7]

Table 4. Standard Efficiency Equipment

Reference House	Equipment
Gas	80 AFUE gas furnace + 13 SEER air conditioner (CZ 5-7) or 14 SEER (CZ 4)
	40 gallon gas natural draft water heater, 0.58 UEF
Electric	14 SEER/8.2 HSPF air source heat pump
	50 gallon electric water heater, 0.92 UEF

Table 5. High Efficiency Equipment Options

Reference House	Equipment
Gas	95 AFUE gas furnace + 16 SEER air conditioner
	Tankless gas direct vent water heater, 0.82 UEF
Electric	16 SEER/10 HSPF inverter heat pump, rated to 7°F (CZ 2-3) or -13°F (CZ 5)
	Heat pump water heater, 50 gal, 2.0 EF

[7] UEF (Uniform Energy Factor) is the current measure of water heater overall efficiency; the higher the UEF value, the more efficient the water heater; UEF is determined by the Department of Energy's test method outlined in 10 CFR Part 430, Subpart B, Appendix E.

Changes for 2021

There are significant changes in the 2021 IECC compared to the 2018 IECC that impact construction cost and energy use cost. Changes to the prescriptive insulation and fenestration requirements include increased ceiling insulation (CZ 2-8), increased continuous insulation on frame walls (CZ 4-5), increased slab insulation (CZ 3-5), and lower window U-factor (CZ 3-4); these changes are shown in Appendix D.

Additional requirements include changes for lighting efficiency and controls; additional air sealing; duct testing even if ducts are entirely inside conditioned space; increased fan efficacy and testing for whole-dwelling ventilation fans; installing an HRV or ERV in CZ 7-8.

The 2021 IECC also has a new section that establishes additional requirements appliable to all compliance approaches to achieve additional energy efficiency (R401.2.5 Additional energy efficiency). The prescriptive approach requires installing one of the five prescribed additional efficiency package options:

- Enhanced envelope performance (5% improvement of UA and SHGC)
- More efficient HVAC equipment performance (minimum 95 AFUE natural gas furnace and 16 SEER air conditioner, 10 HSPF/16 SEER air source heat pump, or 3.5 COP ground source heat pump)
- Reduced energy use in service water-heating (minimum 0.82 EF fossil fuel water heater, 2.0 EF electric water heater, or 0.4 solar fraction solar water heating system)
- More efficient duct thermal distribution system (100% of ducts and air handlers located entirely within the building thermal envelope, 100% ductless systems, or 100% duct system located in conditioned space as defined by Section R403.3.2)
- Improved air sealing (max 3.0 ACH50) and efficient ventilation (ERV or HRV: min 75% SRE; max 1.1 CFM/Watt; shall not use recirculation as a defrost strategy; min 50% LRMT for ERV). For this study, when evaluating this option, the ERV (CZ 2-4) or HRV (CZ 5-7) was modeled in accordance with the 2021 IRC that provides for a ventilation rate credit of 30% where certain criteria are met; houses in CZ 2 were also modeled with a tighter building enclosure (3 ACH50 instead of 5 ACH50).

For houses that already meet the requirements for the efficient duct option (e.g., ducts and air handlers located entirely inside conditioned space) or efficient ventilation/improved air sealing option (e.g., HRV or ERV is now required in CZ 7), no additional efficiency package is required; otherwise, one of the efficiency packages must be selected at additional cost. For this study, the methodology defines houses with basement and conditioned crawlspace foundations as having ducts and air handlers inside conditioned space, and houses with slab and vented crawlspace foundatons as having some ducts outside of conditioned space. Therefore, only houses with slab and vented crawlspace foundations were evaluated for the efficient duct option.

The enhanced envelope option was not evaluted for this study due to it is not considered a reasonably viable option for builders at this time.

For the 2021 IECC, 10 code changes were identified that are considered to have a direct impact on energy use in residential buildings, for a sufficient number of new homes, and which can be reasonably quantified in estimating energy impact. Those 10 changes were included in the energy modeling and are identified in Table 6 with an asterisk.

RESULTS

Construction Costs

The incremental construction costs for the individual code changes that were selected to be evaluated for this study are summarized in Table 6. The cost details are provided in Appendix A for individual changes; Appendix B shows costs by climate zone. The weighted averages of construction costs are shown in Table 7. Changes that represent potential additional construction costs that may or may not affect the Reference House are shown separately in Table 8.

Table 6. Incremental Construction Cost of Individual Code Change for the Reference House

Proposal	Description	Affected CZ	Reference House
RE7*	Lighting: revised definition of high-efficacy	All	$0
RE18/20/21	Certificate: additional info	All	$99
RE29*	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4-5	$4,970
RE32*	Slab edge: NR to R10/2 (CZ3)	3	$1,988
"	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$993
RE33*	Ceiling insulation R38 to R49	2-3	$1,366
RE36*	Ceiling insulation R49 to R60	4-7	$1,366
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA
RE35*	Windows: reduces U-value from 0.32 to 0.30	3-4	$76
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$13
RE49	Baffles at attic access	All	$12
RE72	Air seal narrow framing cavities	All	$156
RE82	Air seal rim (basement; unvented crawlspace)	All	$1,252
"	Air seal rim (slab, vented crawlspace)	All	$417
RE96	House tightness, allows trade-off for performance path	All	$0
RE103	Air seal electrical & communication outlet boxes	All	$369
RE106	Thermostat: requires 7-day programming	All	$0
RE112	Removes exception for duct test (basement, unvented crawl)	All	$247
RE130	Adds requirement to test whole-dwelling ventilation	All	$62
RE133*	Updates ventilation fan efficacy (affects bath EF)	All	$66
RE139*	Requires ERV/HRV in CZ 7-8 (includes RE134 reqs.)	7	$3,206
RE145*	Lighting: 100% high-efficacy; controls (slab)	All	$49
"	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$60
RE148	Lighting, commercial	All	NA
RE149	Lighting: exterior controls	All	$25
RE151	Performance path backstop: 2009 IECC	All	NA
RE178	Performance path ventilation type to match proposed	All	NA
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$15
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA

RE209*	Additional efficiency package options:	All	
	HVAC, gas house, 95 AFUE/16 SEER for 13 SEER baseline	5-7	$1,494
	HVAC, gas house, 95 AFUE/16 SEER for 14 SEER baseline	4	$1,317
	HVAC, electric house, 10 HSPF/18 SEER heat pump rated to 7F	2-3	$5,721
	HVAC, electric house, 10 HSPF/16 SEER (10/18, rated -13F)	5	$8,196
	Water Heater, gas house, tankless direct-vent, 0.82 UEF	All	$740
	Heat Pump Water Heater, electric house, 50 gal, 2.0 EF	2-3	$1,331
	Ventilation, gas house	4-7	$3,206
	Ventilation, electric house	3-5	$3,109
	Ventilation, electric house with improved air tightness	2	$4,591
	Duct, slab house, buried ducts in attic	2-3	$4,125
	Duct, slab house, buried ducts in attic	4-7	$1,736
	Duct, vented crawlspace house	3	($852)
	Duct, vented crawlspace house	4	($193)
*Indicates a code change that was included in the energy modeling analysis for this study (10 total)			

Table 7. Incremental Construction Cost for 2021 Reference House, weighted averages

	National	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7
Configuration	**Average**	**Phoenix**	**Memphis**	**Baltimore**	**Chicago**	**Helena**	**Duluth**
Total without additional efficiency package options	$5,477	$2,648	$4,326	$8,550	$8,695	$3,685	$6,618
Total with HVAC option	$9,301	$8,369	$10,047	$9,867	$10,188	$5,179	$8,112
Total with Water Heater option	$6,548	$3,979	$5,657	$9,290	$9,435	$4,426	$7,358
Total with Ventilation option	$9,011	$7,238	$7,435	$11,755	$11,900	$6,891	$6,618
Total with Duct option, slab house	$8,550	$6,773	$8,451	$10,286	$10,431	$5,421	$8,354
Total with Duct option, vented crawlspace house			$3,474	$8,356			

Table 8. Potential Additional Cost of Individual Code Change for the Reference House

Proposal	Description	Affected CZ	Reference House
RE47	Attic pull-down stair: adds exception to insulation requirements	2-3	($90)
	Same	4	($119)
RE49	Baffles at tray ceiling (example)	2-3	$183
	Same	4-7	$231
RE52	Walls: removes exception for reduced c.i. at WSP	3-7	$640-$2,652
RE55	Adds requirements for unconditioned basements	4-5	$59
RE109	Floor insulation for ducts in conditioned space: min R19	2	$87
RE134	Adds min efficacy for air handlers if integrated w/ventilation	All	$1,222

Energy Use Costs and Savings

The modeling results for annual energy use costs are shown in Table 9. The estimated energy savings, as a percentage of energy use costs, are shown in Table 10. The values shown in Table 9 and Table 10 are weighted averages; energy use details are provided in Appendix E.

Cost Effectiveness

The construction costs (Table 7) and annual energy use costs (Table 9) provide the basis to calculate simple paybacks, shown in Table 11.

Table 9. Annual Energy Use Cost for Reference House, weighted averages

Configuration	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2018 baseline, all houses	$2,129	$2,224	$2,027	$1,934	$2,280	$2,388	$2,599
slab houses only	$2,074	$2,224	$2,024	$1,807	$2,156	$2,221	$2,735
vented crawl houses only			$1,959	$1,826			
2021 without additional efficiency package options	$2,016	$2,163	$1,890	$1,797	$2,137	$2,310	$2,514
2021 with HVAC option	$1,882	$2,045	$1,768	$1,680	$1,959	$2,113	$2,266
2021 with Water Heater option	$1,922	$2,028	$1,741	$1,761	$2,106	$2,283	$2,505
2021 with Ventilation option	$1,994	$2,144	$1,876	$1,778	$2,104	$2,251	$2,495
2021 with Duct option, slab house	$1,851	$2,046	$1,789	$1,585	$1,889	$1,985	$2,418
2021 with Duct option, vented crawlspace house			$1,845	$1,644			

Table 10. Energy Cost Savings relative to 2018 Baseline Reference House

Configuration	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options	5.3%	2.7%	6.8%	7.1%	6.3%	3.3%	3.3%
2021 with HVAC option	11.6%	8.0%	12.8%	13.1%	14.1%	11.5%	12.8%
2021 with Water Heater option	9.7%	8.8%	14.1%	8.9%	7.7%	4.4%	3.6%
2021 with Ventilation option	6.4%	3.6%	7.5%	8.1%	7.7%	5.7%	na
2021 with Duct option, slab house	10.7%	8.0%	11.6%	12.3%	12.4%	10.6%	11.6%
2021 with Duct option, vented crawlspace house			5.8%	10.0%			

Table 11. Simple Payback relative to 2018 Baseline Reference House, years

Configuration	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options	48	43	31	62	61	47	78
2021 with HVAC option	38	47	39	39	32	19	24
2021 with Water Heater option	32	20	20	54	54	42	79
2021 with Ventilation option	67	90	49	75	68	50	63
2021 with Duct option, slab house	38	38	36	46	39	23	26
2021 with Duct option, vented crawlspace house			30	46			

As mentioned in the Methodology section, houses were evaluated based on using either natural gas or electricity as the fuel for heating and hot water: electric in CZ 2-3; gas in CZ 4-7. To illustrate the difference in energy savings for comparison purposes by way of an example, houses in CZ 3 were also modeled using gas, and sample results are shown in Table 12. For houses with the water heater option, the energy savings decreased from 14.1% for electric houses (from Table 10) to 9.9% for gas houses, with a weighted average of 12.2%; the national average energy savings decreased from 9.7% (from Table 10) to 9.3%.

Table 12. Example Comparison of Gas vs. Electric Energy Cost Savings relative to 2018 baseline

	CZ 3 Memphis			National
Configuration	Electric	Gas	Weighted Ave*	Average
2021 without additional efficiency package options	6.8%	7.6%	7.1%	5.5%
2021 with Water Heater option	14.1%	9.9%	12.2%	9.3%
*Weighted average based on 55% electric houses and 45% gas houses, adapted from ABPS				

Cost Effectiveness of Selected Code Changes

Individual code changes were selected for evaluation. The results are shown by applicable climate zone for thermal envelope changes in Tables 13 through 16, the required HRV in CZ 7 in Table 17, and the additional efficiency package options in Tables 18 through 21.

Table 13. Incremental Construction Cost of Thermal Envelope Changes

	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7
Component	**Phoenix**	**Memphis**	**Baltimore**	**Chicago**	**Helena**	**Duluth**
Ceiling insulation	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366
Slab insulation		$1,988	$993	$993		
Wall continuous insulation			$4,970	$4,970		
Window U-factor		$76	$76			

Table 14. Annual Energy Use Cost of Thermal Envelope Changes

	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7
Configuration	**Phoenix**	**Memphis**	**Baltimore**	**Chicago**	**Helena**	**Duluth**
2018 baseline, all houses	$2,224	$2,027	$1,934	$2,280	$2,388	$2,599
2018 baseline, slab houses only		$2,024	$1,807	$2,156		
2018 + 2021 ceiling insulation	$2,216	$2,016	$1,925	$2,268	$2,376	$2,584
2018 + 2021 slab insulation, slab houses only		$1,936	$1,772	$2,120		
2018 + 2021 wall continuous insulation			$1,886	$2,217		
2018 + 2021 window U-factor		$2,020	$1,924			

Table 15. Energy Cost Savings of Thermal Envelope Changes relative to 2018 Baseline Reference House

	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7
Configuration	**Phoenix**	**Memphis**	**Baltimore**	**Chicago**	**Helena**	**Duluth**
2018 + 2021 ceiling insulation	0.3%	0.6%	0.5%	0.5%	0.5%	0.6%
2018 + 2021 slab insulation, slab houses only		4.3%	1.9%	1.7%		
2018 + 2021 wall continuous insulation			2.5%	2.8%		
2018 + 2021 window U-factor		0.3%	0.5%			

Table 16. Simple Payback relative to 2018 Baseline Reference House for Thermal Envelope Changes, years

	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7
Configuration	**Phoenix**	**Memphis**	**Baltimore**	**Chicago**	**Helena**	**Duluth**
2018 + 2021 ceiling insulation	177	122	152	118	105	90
2018 + 2021 slab insulation, slab houses only		23	28	28		
2018 + 2021 wall continuous insulation			103	78		
2018 + 2021 window U-factor		11	7			

Table 17. Cost effectiveness of HRV in CZ 7

Configuration	CZ 7 Duluth
Incremental cost of HRV	$3,206
Annual energy cost, 2021* without HRV	$2,538
Annual energy cost, 2021* with HRV	$2,514
Energy cost savings for HRV	1.0%
Simple payback, years	131

*Without additional efficiency package options

Table 18. Incremental Construction Cost of Additional Efficiency Package Options

Component	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	$5,721	$5,721	$1,317	$1,494	$1,494	$1,494
Water heater option	$1,331	$1,331	$740	$740	$740	$740
Ventilation option	$4,591	$3,109	$3,206	$3,206	$3,206	
Duct option, slab house	$4,125	$4,125	$1,736	$1,736	$1,736	$1,736
Duct option, vented crawlspace house		($852)	($193)			

Table 19. Annual Energy Use Cost of Additional Efficiency Package Options

Configuration	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options, all houses	$2,163	$1,890	$1,797	$2,137	$2,310	$2,514
slab houses only	$2,163	$1,867	$1,655	$1,999	$2,165	$2,639
vented crawlspace houses only		$1,890	$1,711			
2021 with HVAC option	$2,045	$1,768	$1,680	$1,959	$2,113	$2,266
2021 with Water Heater option	$2,028	$1,741	$1,761	$2,106	$2,283	$2,505
2021 with Ventilation option	$2,144	$1,876	$1,778	$2,104	$2,251	$2,495
2021 with Duct option, slab house	$2,046	$1,789	$1,585	$1,889	$1,985	$2,418
2021 with Duct option, vented crawlspace		$1,845	$1,644			

Table 20. Energy Cost Savings of Additional Efficiency Package Options relative to 2021 without packages

Configuration	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	5.4%	6.4%	6.5%	8.3%	8.5%	9.9%
Water Heater option	6.2%	7.9%	2.0%	1.5%	1.2%	0.3%
Ventilation option	0.9%	0.7%	1.1%	1.5%	2.6%	0.8%
Duct option, slab house	5.4%	4.2%	4.2%	5.5%	8.3%	8.4%
Duct option, vented crawlspace house		2.4%	3.9%			

Table 21. Simple payback of efficiency package options relative to 2021 house without packages, years

Configuration	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
HVAC option	49	47	11	8	8	6
Water Heater option	10	9	21	24	27	89
Ventilation option	240	226	167	97	54	0
Duct option, slab house	35	53	25	16	10	8
Duct option, vented crawlspace house		0	0			

CONCLUSIONS

Home Innovation conducted a cost effectiveness analysis of the 2021 IECC code changes for residential construction based on incremental construction costs and energy use costs developed for a Standard Reference House with multiple configurations and in multiple locations.

Key findings are summarized here for the 2021 Reference House relative to the 2018 Baseline Reference House, based on weighted averages within climate zones (foundation type, wall type) and across climates for national averages (based on housing starts):

- The national average incremental construction cost ranges from $6,548 to $9,301 depending on the additional efficiency package option selected for compliance.
- Depending on climate zone, the weighted average incremental construction cost may range up to $11,900.
- The national average energy use cost savings ranges from 6.4% to 11.6% depending on the additional efficiency package option selected for compliance.
- The national average simple payback for complying with the 2021 IECC ranges from 32 years to 67 years.
- The average simple paybacks for selected individual envelope code changes within associated climate zones are 78-103 years for wall continuous insulation, 23-28 years for slab insulation, and 90-177 years for ceiling insulation.
- The average simple payback for the additional efficiency package options within associated climate zones is 6-11 years for natural gas heating and 47-49 years for heat pump heating, 9-10 years for a heat pump water heater in CZ 2-3 relative to a conventional resistance water heater and 21-27 years for a natural gas water heater (except 89 years for a gas water heater in CZ 7), 54-240 years for Ventilation option, 25-53 years for Duct option for slab houses in CZ 2-4 and 8-16 years for Duct option in CZ 5-8.

APPENDIX A: COST OF INDIVIDUAL CODE CHANGES

The estimated construction costs for the selected individual code changes are shown below. Construction costs were developed using RSMeans[8] 2021 Residential Data. Costs for mechanical equipment were sourced from distributor web sites[9]. Costs associated with testing or documentation provided by an energy rater were estimated based on an internet search of rater web sites. See Appendix B for costs by climate zone.

RE7

Reference Code Section

R202 Defined terms; R404.1 Lighting equipment

Summary of the Code Change:

This code change revised the definition of HIGH EFFICACY LIGHT SOURCES. The new minimum efficacy is 65 lumens per watt for lamps and 45 lumens per watt for luminaires. Previously, the minimum efficacy was 60 lumens per watt for lamps over 40 watts, 50 for lamps over 15 watts to 40 watts, and 40 for lamps 15 watts or less (R202). The code change excludes kitchen appliance lighting fixtures from high efficacy requirements for permanently installed lighting fixtures. (R404.1).

Cost Implication of the Code Change:

This code change should not increase the cost of construction as typical CFL and LED lamps meet or exceed the new efficacy requirements. (See RE 145 for lighting changes that do impact cost.)

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[8] RSMeans, https://www.rsmeans.com/

[9] Mechanical equipment cost sources include: hvacdirect.com; supplyhouse.com; acwholesalers.com; menards.com

RE18, RE20, RE21

Reference Code Section

R401.3 Certificate

Summary of the Code Change:

This code change requires additional information on the certificate for PV systems (RE18), code edition and compliance path (RE20), and area-weighted average insulation value (RE21).

Cost Implication of the Code Change:

This code change will increase the cost of construction. The analysis is based on an estimate of the additional time required by a rater to collect and add this information to the certificate.

Cost to add information to the certificate

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Incremental time for rater	HR				80.00	1	80
Total to Builder							**80**
Total to Consumer							**99**

RE29

Reference Code Section

Table R402.1.2; Table R402.1.3

Summary of the Code Change:

This code change increases the prescriptive R-value of continuous insulation (c.i.) on frame walls in CZ 4-5 from “R20 or 13+5” to “R20+5 or 13+10 or 0+15”.

Cost Implication of the Code Change:

This code change will increase the cost of construction for frame walls in CZ 4-5. The analysis is based on the cost to increase c.i. from R5 to R10 for 2x4 walls and from none to R5 for 2x6 walls. The costs include associated additional trim at windows and doors and longer fasteners for cladding based on vinyl siding. A weighted average cost is then determined based on market data for walls (per the 2019 ABPS), as shown below.

Weighted Average Cost to Increase Continuous Insulation (c.i.)

Component	Unit	Cost, from below	Weight	Cost, weighted
2x4 wall, increase c.i. from R5 to R10	$/house	1,101	24.9%	274
2x6 wall, increase c.i. from R0 to R5	$/house	6,504	72.2%	4,696
Total to Consumer				**4,970**

Cost to increase c.i. from R5 to R10 for 2x4 wall

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5	SF	0.68	0.45	1.13	1.49	(2,675)	(3,986)
XPS, 15 psi, 2", R10	SF	0.83	0.49	1.32	1.72	2,675	4,601
Window/door casing, PVC trim exterior	LF	0.55		0.55	0.61	415	251
Siding attachment, 2.5" roofing nail galv	LB	3.06		3.06	3.37	(21)	(71)
Siding attachment, 3.5" common nail galv	LB	1.78		1.78	1.96	49	96
Total to Builder							**892**
Total to Consumer							**1,101**

Cost to increase c.i. from none to R5 for 2x6 wall

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5	SF	0.68	0.45	1.13	1.49	2,675	3,986
Door/window casing, PVC trim exterior	LF	0.55	1.47	2.02	3.03	415	1,258
Siding attachment, 1.5" roofing nail galv	LB	2.78		2.78	3.06	(13.0)	(40)
Siding attachment, 2.5" roofing nail galv	LB	2.78		2.78	3.06	21.0	64
Total to Builder							**5,268**
Total to Consumer							**6,504**

RE32

Reference Code Section

Table R402.1.2, Table R402.1.3

Summary of the Code Change:

This code change increases the slab edge insulation requirements in CZ 3 from none to R10/2 (R10, 2-feet deep) and in CZ 4-5 from 10/2 to 10/4 (R10, 4-feet deep).

Cost Implication of the Code Change:

This code change will increase the cost of construction for slab homes in CZ 3-5. The analysis is based on the cost to install this insulation at the Reference House with a foundation perimeter of 200 linear feet, so the quantity of insulation 2-feet deep is 400 square feet. Note that the incremental quantity and cost of insulation is assumed to be the same for CZ 3 and CZ 4-5; however, for CZ 3, the cost of flashing at the top edge of the insulation is included.

Cost of additional slab edge insulation, CZ 3

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 25 psi, 2" thick, R-10	SF	1.23	0.40	1.63	2.01	400	804
Flashing, vinyl coated aluminum	SF	1.92	1.17	3.09	4.03	200	806
Total to Builder							**1,610**
Total to Consumer							**1,988**

Cost of additional slab edge insulation, CZ 4-5

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 25 psi, 2" thick, R-10	SF	1.23	0.40	1.63	2.01	400	804
Total to Builder							**804**
Total to Consumer							**993**

RE33, RE36

Reference Code Section

Table R402.1.2, Table R402.1.3, R402.2.1

Summary of the Code Change:

These code changes increase ceiling insulation from R38 to R39 in CZ 2-3 (RE33) and from R49 to R60 in CZ 4-8 (RE36). The code change also updates the exception for ceiling insulation above wall top plates at eaves to include where R60 is now required.

Cost Implication of the Code Change:

This code change will increase the cost of construction in CZ 2-8. The analysis is based on the incremental cost of blown fiberglass insulation in a vented attic. The incremental cost is assumed to be the same for both changes. The analysis does not address any potential costs associated with raised-heel trusses.

Cost to Increase ceiling insulation from R-38 to R-49 or from R-49 to R-60

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
R-38 attic insulation, blown fg	SF	0.69	0.61	0.36	1.66	2.14	(1,875)	(4,013)
R-49 attic insulation, blown fg	SF	0.91	0.76	0.45	2.12	2.73	1,875	5,119
Total to Builder								**1,106**
Total to Consumer								**1,366**

RE34

Reference Code Section

Table R402.1.3

Summary of the Code Change:

This code change removed the footnote “g” exception for reduced insulation in floors for CZ 5 and Marine 4 through CZ 8. The deleted exception alternatively allowed insulation sufficient to fill the framing cavity providing not less than an R-value of R-19, instead of the prescribed values of R30 (CZ 5-6 and Marine 4) or R38 (CZ 7-8). Note that the prescribed floor insulation values did not change for 2021.

Cost Implication of the Code Change:

This code change may increase the cost of construction in some cases (e.g., installing spray foam insulation with a higher R-value per inch, or installing taller floor joists to accommodate sufficient insulation, may now be required to meet prescriptive floor insulation values), but there is no cost impact for the Reference House because the Reference House does not have floors above unconditioned space.

RE35

Reference Code Section

Table 402.1.2 and Table R402.1.3

Summary of the Code Change:

This code change reduces the prescriptive maximum U-factor for windows in CZ 3-4 from 0.32 to 0.30. The change also adds a footnote that a maximum window U-factor of 0.32 shall apply in CZ 5/Marine 4 through CZ 8 for buildings located above 4,000 feet in elevation above sea level or in windborne debris regions where protection of openings is required.

Cost Implication of the Code Change:

This code change will increase the cost of construction in CZ 3-4. The analysis is based on an incremental material cost of $0.15/SF for improving window U-factor from 0.32 to 0.30 as determined by the California Energy Commission[10].

The Department of Energy and EPA Energy Star along with those involved in the development of energy codes have traditionally had problems developing a clear incremental cost for changes in window thermal performance. An earlier report based on cost data collected by the U.S. Department of Energy indicated an incremental cost of $0.18/SF window area for improving U-value from 0.35 to 0.32[11]. In this analysis, prices used to develop the incremental cost associated with the code change are a best guess based on the available data.

Cost to reduce the window U-factor from 0.32 to 0.30

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Incremental cost of window	SF	0.15		0.15	0.17	375	62
Total to Builder							**62**
Total to Consumer							**76**

[10] CEC report, see table 9: https://efiling.energy.ca.gov/GetDocument.aspx?tn=222199&DocumentContentId=27369

[11] https://www.energycodes.gov/sites/default/files/documents/iecc2018_R-2_analysis_final.pdf

RE37

Reference Code Section

Table 402.1.2 and Table R402.1.3

Summary of the Code Change:

This code change changes the window SHGC in CZ 5 and CZ 4C Marine from “NR” to “0.40”.

Cost Implication of the Code Change:

It is anticipated that this change will not affect the cost of construction because windows in these climate zones commonly meet the new requirement already. Energy Star criteria include maximum 0.40 SHGC in “North-Central” climates since 2015. Further, energy modeling typically assigns a value of 0.40 where SHGC is NR.

RE105

Reference Code Section

R402.5 Maximum fenestration U-factor and SHGC

Summary of the Code Change:

This code change reduces the average maximum fenestration SHGC permitted using tradeoffs in CZ 0-3 from 0.50 to 0.40.

Cost Implication of the Code Change:

It is anticipated that this change will not affect the cost of construction because windows in these climate zones commonly meet the new requirement already. Energy Star criteria include maximum 0.25 SHGC in “South-Central” and “Southern” climates since 2015.

RE46

Reference Code Section

R402.2.4 Access hatches and doors

Summary of the Code Change:

This code change does not add new requirements; rather, it separates the prescriptive (required insulation levels) and mandatory (weatherstripping) provisions into separate sections.

Cost Implication of the Code Change:

This code change does not directly impact the cost of construction. However, additional insulation is required due to increased prescriptive ceiling insulation requirements. The analysis is based on the cost to install an additional R-11 insulation above a 24” x 36” attic access hatch.

Cost to increase the insulation above an attic access by R-11

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
EPS, 3" thick, R-11.5	SF	0.96	0.40	1.36	1.72	6	10
Total to Builder							**10**
Total to Consumer							**13**

RE47

Reference Code Section

R402.2.4 Access hatches and doors

Summary of the Code Change:

This code change adds an exception to the attic access insulation requirement. Attic pull-down stairs in CZ 0-4 are not required to comply with the insulation level of the surrounding surfaces provided that the hatch meets all the following: average maximum U-0.10 insulation or average minimum R-10 insulation; at least 75% of the panel area shall be minimum R-13 insulation; maximum net area of the framed opening is 13.5 SF; the perimeter of the hatch shall be weatherstripped.

Cost Implication of the Code Change:

This code change may decrease construction costs where pull-down attic stairs are utilized in CZ 0-4. The analysis is based on the cost savings of less insulation above the access: for this study, R13 versus R49 in CZ 2-3, and R13 versus R60 in CZ 4.

Cost savings to reduce insulation above attic pull-down stair for CZ 2-3 (R49 ceiling)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5 (one 1” layer)	SF	0.68	0.45	1.13	1.49	13.5	20
XPS, 15 psi, 2", R10 (one 2” layer)	SF	0.83	0.49	1.32	1.72	13.5	23
XPS, 15 psi, 2", R10 (five 2” layers)	SF	0.83	0.49	1.32	1.72	(67.5)	(116)
Total to Builder							**(73)**
Total to Consumer							**(90)**

Cost savings to reduce insulation above attic pull-down stair for CZ 4 (R60 ceiling)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5 (one 1” layer)	SF	0.68	0.45	1.13	1.49	13.5	20
XPS, 15 psi, 2", R10 (one 2” layer)	SF	0.83	0.49	1.32	1.72	13.5	23
XPS, 15 psi, 2", R10 (six 2” layers)	SF	0.83	0.49	1.32	1.72	(81.0)	(139)
Total to Builder							**(96)**
Total to Consumer							**(119)**

RE49

Reference Code Section

R402.2.4 Access hatches and doors

Summary of the Code Change:

This code change adds a requirement for baffles to prevent loose-fill attic insulation from spilling into higher to lower sections of the attic, and from attics covering conditioned spaces to unconditioned spaces. Baffles at the attic access to prevent spilling into livings space are still required (although those must be taller now).

Cost Implication of the Code Change:

This code change will increase the cost of construction for the attic access hatch. This code change may increase the cost of construction where ceiling height varies or attics above unconditioned spaces.

The analysis develops an incremental cost to construct a taller baffle (by 4") for a 24" x 36" attic access hatch for all CZs. The analysis also develops a cost to install baffles for a hypothetical tray ceiling (est. 48 LF): for blown fiberglass insulation at R-3.2/inch, the baffles would need to be 16" tall plus a 3" nailing surface for CZ 2-3 and 19" tall plus a 3" nailing surface for CZ 4-7.

Cost to increase the height of insulation baffles at attic access hatch

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Plywood, 3/4" CDX	SF	1.38	0.60	1.98	2.50	4	10
Total to Builder							**10**
Total to Consumer							**12**

Cost to add baffles at tray ceiling (est. 48 LF) for CZ 2-3

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Plywood, 1/2" CDX	SF	1.00	0.52	1.52	1.95	76	148
Total to Builder							**148**
Total to Consumer							**183**

Cost to add baffles at tray ceiling (est. 48 LF) for CZ 4-8

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Plywood, 1/2" CDX	SF	1.00	0.52	1.52	1.95	96	187
Total to Builder							**187**
Total to Consumer							**231**

RE52

Reference Code Section

Deleted 2018 IECC R402.2.7 Walls with partial structural sheathing

Summary of the Code Change:

This code change deleted a section that allowed continuous insulation (c.i.) to be reduced, where c.i. is required and structural sheathing covers 40 percent or less of the gross wall area of all exterior walls, to result in a consistent total sheathing thickness on areas of the walls covered by structural sheathing.

Cost Implication of the Code Change:

This code change would increase the cost of construction in CZ 3-8 where the exception was utilized. The analysis is based on the additional cost to increase the foam sheathing thickness to 1-1/2-inch where it was 1-inch before, and to 1-inch where it was ½-inch before over the structural sheathing. A second cost is developed separately based on the additional cost to install ½-inch structural sheathing over the entire wall area and 1-inch thick foam sheathing over the structural sheathing. Both costs are based on using XPS foam sheathing and the assumption that wood structural sheathing originally covered 40% of the wall area (1,070 SF) and the remaining 60% of the wall area (1,605 SF) was originally covered by foam only (i.e., not by wood structural sheathing).

Cost to install additional 1/2-inch thickness of continuous insulation

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1/2", R3	SF	0.60	0.43	1.03	1.37	(1,070)	(1,465)
XPS, 15 psi, 1", R5	SF	0.68	0.45	1.13	1.49	1,070	1,594
XPS, 15 psi, 1", R5	SF	0.68	0.45	1.13	1.49	(1,605)	(2,391)
XPS, 15 psi, 1.5", R7.5	SF	0.76	0.49	1.25	1.64	1,605	2,639
Window/door casing, add 1/2"	LF	0.23		0.28	0.31	415	128
Siding attachment, 2" roofing nail galv	LB	3.06		3.06	3.37	(17)	(57)
Siding attachment, 2.5" roofing nail galv	LB	3.06		3.06	3.37	21	71
Total to Builder							**518**
Total to Consumer							**640**

Cost to install OSB over entire wall and cover with 1-inch XPS

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1/2", R3	SF	0.60	0.43	1.03	1.37	(1,070)	(1,465)
XPS, 15 psi, 1", R5	SF	0.68	0.45	1.13	1.49	1,070	1,594
OSB, wall, 1/2"	SF	0.41	0.44	0.85	1.17	1,605	1,878
Window/door casing, add 1/2"	LF	0.23		0.28	0.31	415	128
Siding attachment, 2" roofing nail galv	LB	3.06		3.06	3.37	(17)	(57)
Siding attachment, 2.5" roofing nail galv	LB	3.06		3.06	3.37	21	71
Total to Builder							**2,148**
Total to Consumer							**2,652**

RE55

Reference Code Section

R402.2.8 Basement walls

Summary of the Code Change:

This code change adds requirements for how to insulate and seal unconditioned basements including at the floor overhead, walls surrounding the stairway, door leading to the basement from conditioned space; the requirements also include no uninsulated duct, domestic hot water or hydronic heating surfaces exposed to the basement, and no HVAC supply or return diffusers serving the basement.

Cost Implication of the Code Change:

This code change will increase the cost of construction where insulation requirements are greater for 2021, i.e., increased continuous insulation (c.i.) for exterior walls in CZ 4-5 for this analysis. The analysis develops a cost to increase c.i. in the walls surrounding the stairway. This analysis assumes that builders were already constructing unconditioned basements as described by the code change.

Cost to increase wall insulation in the stairway

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
XPS, 15 psi, 1", R5	SF	0.68	0.45	1.13	1.49	(200)	(298)
XPS, 15 psi, 2", R10	SF	0.83	0.49	1.32	1.72	200	344
Drywall screw, 2.5"	LB	5.98		5.98	6.58	(1.3)	(9)
Drywall screw, 3.5"	LB	5.98		5.98	6.58	1.6	10
Total to Builder							**48**
Total to Consumer							**59**

RE72

Reference Code Section

Table R402.4.1.1 Air barrier, air sealing and insulation installation

Summary of the Code Change:

This code change adds a new requirement that “narrow cavities of an inch or less that are not able to be insulated shall be air sealed”.

Cost Implication of the Code Change:

This code change may increase the cost of construction as applicable. The analysis is based on an estimated quantity of small cavities that would require the installation of sealant.

Cost to install additional sealant for narrow framing cavities

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Sealant, latex acrylic, 3/4" x 1" bead	LF	1.28	1.28	2.56	3.51	36	126
Total to Builder							**126**
Total to Consumer							**156**

RE82

Reference Code Section

Table R402.4.1.1 Air barrier, air sealing and insulation installation

Summary of the Code Change:

This code change adds a new requirement to air seal the rim board at the sill plate and subfloor. Rim areas in vented crawl spaces and attics are exempt.

Cost Implication of the Code Change:

This code change will increase the cost of construction. The analysis is based on the linear feet of sealant required for the Reference House designs with a foundation perimeter of 200 LF and a second story perimeter of 100 LF. For basement and unvented crawlspace designs, the quantity of sealant is 600 LF (300 LF of rim area, multiplied by two to capture the sealant required at both the sill plate and subfloor). For slab and vented crawlspace designs, the quantity of sealant is 200 LF (100 LF of rim area for the second floor).

Cost to install sealant at rim joists for basement or unvented crawlspace designs

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Sealant, latex acrylic, 1/4" x 1/4" bead	LF	0.10	0.96	1.06	1.69	600	1,014
Total to Builder							**1,014**
Total to Consumer							**1,252**

Cost to install sealant at rim joists for slab or vented crawlspace designs

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Sealant, latex acrylic, 1/4" x 1/4" bead	LF	0.10	0.96	1.06	1.69	200	338
Total to Builder							**338**
Total to Consumer							**417**

RE96

Reference Code Section

R402.4.1.2 Testing

Summary of the Code Change:

This code change makes house air tightness prescriptive and allows a trade-off option up to 5.0 ACH50 or 0.28 CFM/SF enclosure area (0.30 CFM/SF exception for attached dwellings and dwellings 1,500 SF or smaller). The prescriptive limits remain the same: 5.0 ACH50 in CZ 1-2; 3.0 ACH50 in CZ 3-8.

Cost Implication of the Code Change:

This code change may decrease construction costs in some cases where a builder trades-off air leakage for other efficiency improvements for a house in CZ 3-8, but there is assumed to be no cost impact for the Reference House because there is not a straightforward approach to reasonably quantify such a change.

RE103

Reference Code Section

R402.4.6 Electrical and communication outlet boxes (air-sealed boxes)

Summary of the Code Change:

This code change adds a new section that requires electrical and communication outlet boxes installed in the building thermal envelope (i.e., exterior walls and ceilings adjacent to vented attics) to be air sealed. These outlet boxes must be tested and labeled in accordance with NEMA OS 4.

Cost Implication of the Code Change:

This code change will increase the cost of construction for all locations. The analysis is based on the cost to substitute a rated airtight box for a standard blue plastic new-work electrical box, using an estimated quantity of affected boxes for the Reference House.

Cost of air sealed electrical and communication outlet boxes

Component	Unit	Material	Labor	Total	w/O&P	Quantity*	Cost
Standard electric box, 1-gang	EA	0.34		0.34	0.37	(42)	(16)
NEMA OS 4 Airtight box, 1-gang	EA	5.52		5.52	6.07	42	255
Standard electric box, ceiling	EA	1.19		1.19	1.31	(10)	(13)
NEMA OS 4 Airtight box, ceiling	EA	6.60		6.60	7.26	10	73
Total to Builder							**299**
Total to Consumer							**369**

***Estimated quantity of affected boxes**

Box type	Quantity
Wall receptacle outlet (one every 10 LF of exterior wall)	30
Wall switch outlet	6
Wall communication outlet	6
Ceiling light fixture/smoke detector	10

RE106

Reference Code Section

R403.1.1 Programmable thermostat

Summary of the Code Change:

This code change modifies the required capabilities for programmable thermostats: in addition to being capable of controlling different set point temperatures at different times of the day, thermostats must now be capable of controlling this for different days of the week (i.e., a 7-day thermostat, versus a 5-2 day or 5-1-1 day).

Cost Implication of the Code Change:

This code change may increase the cost of construction in some cases, depending on the make and model of thermostat normally used, but a review of distributor websites indicated the lowest cost programmable thermostat by a leading national manufacturer already has 7-day capability for single-stage heat pump or gas furnace with air conditioner systems. Therefore, this code change is not anticipated to affect the cost of construction. There is not an energy use cost savings associated with this change because the energy modeling does utilize thermostat set-back settings.

RE109

Reference Code Section

R403.3.2 Ducts located in conditioned space

Summary of the Code Change:

This code change adds requirements for ducts within floor or wall cavities to be considered ducts in conditioned space. The requirements include minimum R-19 insulation for floors above unconditioned space, e.g., above a garage, so there are implications for CZ 1-2 where the prescriptive minimum floor insulation is R-13.

Cost Implication of the Code Change:

This code change may increase the cost of construction in some cases although the Reference House does not have floors above unconditioned space and it is assumed there are no ducts within any wall cavities. The analysis is based on the incremental cost to install R-19 floor insulation instead of R-13 above a garage, assuming ducts occupy two joist bays (each 2' wide x 20' long), and to substitute oval duct for round duct so that the oval duct (typically 3") plus the R-19 insulation (typically 5.5") fits within the height of a 2x10 floor joist.

Cost to increase floor insulation within joist bay from R-13 to R-19

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
R-13 unfaced fiberglass batt	SF	0.49	0.42	0.91	1.22	(80)	(98)
R-19 unfaced fiberglass batt	SF	0.60	0.49	1.09	1.46	80	117
7" round metal duct	LF	2.00		2.00	2.20	(40)	(88)
7" oval metal duct	LF	3.16		3.16	3.48	40	139
Total to Builder							**70**
Total to Consumer							**87**

RE112

Reference Code Section

R403.3.5 Duct testing, R403.3.6 Duct leakage

Summary of the Code Change:

This code change removes the exception for testing where ducts and air handlers are located entirely within the building thermal envelope (R403.3.5). The code change also increases the total leakage limit from 4.0 to 8.0 CFM25/100SFcfa where ducts and air handlers are located entirely within the building thermal envelope (R403.3.6).

Cost Implication of the Code Change:

This code change will increase the cost of construction where ducts and air handlers are already installed in conditioned space but testing for duct leakage is now required. The analysis is based on a typical charge by a rater to conduct this test during the same visit as the house tightness test. Any cost of remediation for a failed test is not included. For the Reference Houses, it is assumed that this test will now be required for basement and unvented crawlspace designs.

Estimated cost of the duct leakage test

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Charge by rater	EA				200.00	1	200
Total to Builder							**200**
Total to Consumer							**247**

RE130

Reference Code Section

R403.6.3 Testing (new)

Summary of the Code Change:

This code change requires whole-dwelling mechanical ventilation systems to be tested and verified to provide the minimum required ventilation flow rates.

Cost Implication of the Code Change:

This code change will increase the cost of construction for all houses. The analysis is based on a typical charge by a rater to conduct this test during the same visit as the house tightness test. Testing is in addition to duct leakage testing. Testing is now required for the ventilation system of record (e.g., bath exhaust fan, HRV/ERV, supply-type ducted to the return plenum of a central system). Any cost of remediation for a failed test is not included.

Estimated cost of the mechanical ventilation test

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Charge by rater	EA				50.00	1	50
Total to Builder							**50**
Total to Consumer							**62**

RE133

Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

Summary of the Code Change:

This code change updates the fan efficacy requirements for fans used to provide whole-dwelling mechanical ventilation (supply and exhaust fans now must meet the current EnergyStar requirements). The minimum efficacy for an exhaust fan increased from 1.4 to 2.8 CFM/watt for airflow rates less than 90 CFM and from 2.8 to 3.5 CFM/watt for airflow rates 90 CFM and above. The minimum efficacy for an ERV/HRV did not change.

Cost Implication of the Code Change:

This code change may increase the cost of construction in some cases depending on the make and model of fan already being installed. The Reference House uses a bath exhaust fan for whole-dwelling mechanical ventilation and requires a continuous ventilation rate of 63 CFM for slab and crawlspace designs or 82 CFM for basement designs. The analysis is based on the case where an exhaust fan with an efficacy of at least 1.4 CFM/watt but less than 2.8 CFM/watt must be replaced with unit with efficacy of at least 2.8 CFM/watt.

Incremental cost of high efficacy bath exhaust fan

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, 1.8 CFM/W (Air King)	EA	40.15		40.15	44.17	(1)	(44)
Bath fan, 90 CFM, EnergyStar (Air King)	EA	88.43		88.43	97.27	1	97
Total to Builder							**53**
Total to Consumer							**66**

RE134

Reference Code Section

R403.6 Mechanical ventilation, Table R403.6.2

Summary of the Code Change:

This code change adds efficacy requirements to air-handlers where integrated with whole-dwelling mechanical ventilation: minimum 1.2 cfm/watt, the "design outdoor airflow rate/watts of fan used".

Cost Implication of the Code Change:

This code change may increase the cost of construction for integrated supply-type ventilation (ducted to the return plenum of the HVAC system) or balanced ventilation that is partially ducted (HRV or ERV ducting integrated with the HVAC system).

This change does not impact the Reference House that utilizes exhaust ventilation. However, a cost is developed for supply-type ventilation (this cost will also be a component of installing balanced ventilation where an HRV or ERV is integrated with the central duct system). The analysis is based on substituting a variable-speed furnace (constant-airflow ECM air drive) for a multi-speed furnace (constant-torque ECM air drive) to meet the efficacy requirement. During fan-only operation (no heating or cooling), the variable-speed furnace or air handler can be adjusted to operate at 25% of normal heating or cooling airflow, and at this lower airflow system will generally meet the efficacy requirement (although this value is typically not published in the manufacturer product data). Additionally, at this lower airflow, the differential pressure at the return plenum will not be sufficient to draw in the required amount of outdoor air, so an additional ventilation fan will normally be required. The analysis assumes the existing ventilation control is already accounted for.

Incremental cost of variable-speed furnace

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gas furnace, 80 AFUE, multi-speed	EA	818.00		818.00	899.80	(1)	(900)
Gas furnace, 80 AFUE, variable-speed	EA	1323.00		1323.00	1455.30	1	1,455
Total to Builder							**556**
Total to Consumer							**686**

Cost of both variable-speed furnace and ventilator fan

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Furnace, total to Builder from above							556
Ventilator fan with damper	EA	293.04	39.90	332.94	388.18	1	388
Ventilation damper	EA	85.99		85.99	94.59	(1)	(95)
15-amp circuit, duplex outlet, 20' 14/2 NM	EA	7.30	23.50	30.80	46.00	1	46
Wire, 14/2, add 20'	LF	0.17	1.37	1.54	2.41	20	48
GFCI 15-amp 1-pole breaker	EA	41.99		41.99	46.19	1	46
Total to Builder							**989**
Total to Consumer							**1,222**

RE139

Reference Code Section

R403.6.1 Heat or energy recovery ventilation (new)

Summary of the Code Change:

This code change requires an HRV or ERV system in CZ 7-8. The system shall be balanced with a minimum 65% SRE at 32°F at a flow greater than or equal to design airflow.

Note that in the 2021 IRC, Section M1505.4.3, there is a whole-dwelling ventilation rate credit of 30% available for a balanced ventilation system with a ducted supply to each bedroom and to one or more of the following rooms: living room; dining room; kitchen.

Cost Implication of the Code Change:

This code change will increase the cost of construction in CZ 7-8. The analysis develops a cost to install an ERV that meets the efficiency requirements and substitutes a standard bath fan for a high efficacy fan that was used for exhaust-type whole-dwelling ventilation. The cost also includes substituting a variable-speed furnace (constant-airflow ECM air drive) for a multi-speed furnace (constant-torque ECM air drive) to meet the efficacy requirement for air handlers integrated with whole-dwelling mechanical ventilation (RE134); alternatively, the ERV would need to be ducted independently.

Cost to install an ERV

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)	EA	88.43		88.43	97.27	(1)	(97)
Bath exhaust fan controller	EA	56.60		56.60	62.26	(1)	(62)
Bath exhaust fan, standard	EA	28.24		28.24	31.06	1	31
Gas furnace, 80 AFUE, multi-speed blower	EA	818.00		818.00	899.80	(1)	(900)
Gas furnace, 80 AFUE, variable-speed blower	EA	1323.00		1323.00	1455.30	1	1,455
ERV, 100 CFM	EA	991.99		991.99	1091.19	1	1,091
HRV/ERV controller	EA	82.99		82.99	91.29	1	91
Installation, labor	HR		39.90	39.90	65.84	2	132
Installation, material	EA	40.00		40.00	44.00	1	44
15-amp circuit, duplex outlet, 20' 14/2 NM	EA	7.30	23.50	30.80	46.00	1	46
Wire, 14/2, add 20'	LF	0.17	1.37	1.54	2.41	20	48
GFCI 15-amp 1-pole breaker	EA	41.99		41.99	46.19	1	46
Grille, exhaust (from house)	EA	35.00	14.50	49.50	62.50	1	63
Duct, flexible insulated, 6" dia	LF	3.81	2.21	6.02	7.85	50	393
Wall cap, 6" dia duct	EA	54.50	29.00	83.50	108.00	2	216
Total to Builder							**2,597**
Total to Consumer							**3,206**

RE145

Reference Code Section

R404.1 Lighting equipment; R404.2 Interior lighting controls (new)

Summary of the Code Change:

This code change mandates that all permanently installed lighting fixtures contain only high-efficacy lamps (previously 90%) and have built-in lighting controls (dimmer, occupant sensor, or other control) excluding bathrooms, hallways, exterior lighting fixtures, lighting designed for safety or security.

Cost Implication of the Code Change:

This code change will increase the cost of construction for all houses. The analysis is based on an estimated quantity of high-efficacy lamps and dimmers required at the Reference Houses.

Cost of high-efficacy lamps and dimmer switches (slab)

Component	Unit	Material	Labor	Total	w/O&P	Quantity*	Cost
CFL lamp	EA	1.99		1.99	2.19	4	9
Incandescent lamp	EA	1.02		1.04	1.12	(4)	(4)
Dimmer switch, toggle	EA	9.99		9.99	10.99	4	44
Standard toggle switch	EA	1.99		1.99	2.19	(4)	(9)
Total to Builder							**39**
Total to Consumer							**49**

Cost of high-efficacy lamps and dimmer switches (basement or crawl space)

Component	Unit	Material	Labor	Total	w/O&P	Quantity*	Cost
CFL lamp	EA	1.99		1.99	2.19	4	9
Incandescent lamp	EA	1.02		1.99	1.12	(4)	(4)
Dimmer switch, toggle	EA	9.99		9.99	10.99	5	55
Standard toggle switch	EA	1.99		1.99	2.19	(5)	(11)
Total to Builder							**48**
Total to Consumer							**60**

***Quantities**

Room	Lamps	Dimmer
Dining room	6	1
Kitchen	6	1
Breakfast	4	1
Family Room	2	1
Halls	2	0
Baths (3)	10	0
Bedrooms	0	0
Exterior	2	0
Basement or crawlspace	4	1
Total, basement or crawl	36	5
Total, slab	32	4
Additional lamps required	4	

RE148

Reference Code Section

R404.1.1 Exterior lighting

Summary of the Code Change:

This code change requires compliance with Section C405.4 of the IECC for connected exterior lighting for Group R-2, R-3, and R-4 buildings.

Cost Implication of the Code Change:

This code change will not impact the cost of construction for homes constructed to the IRC.

RE149

Reference Code Section

R404.3 Exterior lighting controls (new)

Summary of the Code Change:

This code change requires automatic controls where permanently installed exterior lighting power exceeds 30 watts.

Cost Implication of the Code Change:

This code change may increase the cost of construction. The analysis assumes two 100-watt equivalent, 18-watt actual, exterior lamps and is based on installing two light-sensing devices.

Cost of exterior lighting control with light sensor

Component	Unit	Material	Labor	Total	w/O&P	Quantity*	Cost
Control, 100-watt rated, screw-in type	EA	9.20		9.20	10.12	2	20
Total to Builder							**20**
Total to Consumer							**25**

RE151

Reference Code Section

R405.2

Summary of the Code Change:

This code change creates a backstop for the performance path that requires the building thermal envelope greater than or equal to levels of efficiency and solar heat gain coefficients in the 2009 IECC.

Cost Implication of the Code Change:

It is anticipated that this change will not affect the cost of construction.

RE178

Reference Code Section

Table R405.4.2

Summary of the Code Change:

This code change updates the mechanical ventilation system type for the standard reference design to match the proposed design when using the performance compliance option.

Cost Implication of the Code Change:

It is anticipated that this change will not affect the cost of construction.

RE209

Reference Code Section

R401.2.5 Additional energy efficiency (new); R408 Additional efficiency package options (new)

Summary of the Code Change:

This code change establishes additional requirements appliable to all compliance approaches to achieve additional energy efficiency. Compliance for the prescriptive approach requires installing at least one of the five prescribed efficiency package options:

- Enhanced envelope performance (5% UA and SHGC improvement)
- More efficient HVAC equipment performance (minimum 95 AFUE natural gas furnace and 16 SEER air conditioner, 10 HSPF/16 SEER airs source heat pump, or 3.5 COP ground source heat pump)
- Reduced energy use in service water-heating (minimum 0.82 EF fossil fuel water heater, 2.0 EF electric water heater, or 0.4 solar fraction solar water heating system)
- More efficient duct thermal distribution system (100% of ducts and air handlers located entirely within the building thermal envelope, 100% ductless systems, or 100% duct system located in conditioned space as defined by Section R403.3.2)
- Improved air sealing (max 3.0 ACH50) and efficient ventilation (ERV or HRV: min 75% SRE; max 1.1 CFM/Watt; shall not use recirculation as a defrost strategy; min 50% LRMT for ERV). [For this study, when evaluating this option, the ERV (CZ 2-4) or HRV (CZ 5-7) was modeled in accordance with the 2021 IRC that provides for a ventilation rate credit of 30% where certain criteria are met, and houses in CZ 2 were modeled with a tighter building enclosure (3 ACH50 instead of 5 ACH50)].

Cost Implication of the Code Change:

This code change will increase the cost of construction. The analysis evaluates the costs associated with the additional efficiency package options except for the enhanced envelope option.

HVAC equipment option for Gas House with baseline 13 SEER AC (CZ 5-7 for this study)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Gas furnace, 80kBtuh, AFUE 80%	EA	761.00		761.00	837.10	(1)	(837)
Gas Chimney Vent, 4" dia.	LF	9.65	8.45	18.10	24.50	(25)	(613)
Gas Chimney Vent, 3" dia. (water heater)	LF	7.95	8.00	15.95	22.00	25	550
Gas furnace, 80kBtuh, AFUE 95%	EA	1,295.00		1,295.00	1,424.50	1	1,425
Vent piping, PVC, 2" dia.	LF	3.05	3.02	6.07	8.30	40	332
2" concentric vent kit	EA	59.95		59.95	65.95	1	66
Condenser, 3 ton, 13 SEER	EA	1,085.00		1,085.00	1,193.50	(1)	(1,194)
Condenser, 3 ton, 16 SEER	EA	1,346.00		1,346.00	1,480.60	1	1,481
Total to Builder							**1,210**
Total to Consumer							**1,494**

HVAC equipment option for Gas House adjusted for baseline 14 SEER AC (CZ 2-4 for this study)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Total to Builder, from above							**1,210**
Condenser, 3-ton, 14 SEER	EA	1,215.00		1,215.00	1,336.50	(1)	(1,337)
Condenser, 3-ton, 13 SEER	EA	1,085.00		1,085.00	1,193.50	1	1,194
Total to Builder							**1,067**
Total to Consumer							**1,317**

HVAC option for Electric House: variable speed inverter heat pump, rated to 7F (CZ 2-4)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Heat Pump, 8.2 HSPF/14 SEER	EA	1,629.00		1,629.00	1,791.90	(1)	(1,792)
Air Handler, matching	EA	988.00		988.00	1,086.80	(1)	(1,087)
Heat Pump, inverter, minimum 10 HSPF/16 SEER, 7F rated	EA	6,830.00		6,830.00	7,513.00	1	7,513
Total to Builder							**4,634**
Total to Consumer							**5,721**

HVAC option for Electric House: variable speed inverter heat pump, rated to -13F (CZ 5-7)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Heat Pump, 8.2 HSPF/14 SEER	EA	1,629.00		1,629.00	1,791.90	(1)	(1,792)
Air Handler, matching	EA	988.00		988.00	1,086.80	(1)	(1,087)
Heat Pump, inverter, minimum 10 HSPF/16 SEER, -13F rated	EA	8,652.00		8,652.00	9,517.20	1	9,517
Total to Builder							**6,639**
Total to Consumer							**8,196**

Water Heater option for Gas House: Tankless Direct Vent Water Heater

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
40 gal gas water heater, 0.58 UEF	EA	559.00	165.00	724.00	883.52	(1)	(884)
Tankless gas water heater, 0.82 UEF	EA	799.00	174.00	973.00	1,162.17	1	1,162
Concentric vent wall termination kit	EA	90.00		90.00	99.00	1	99
Concentric vent 39" extension	EA	37.59		37.59	41.35	1	41
Gas Chimney Vent, 3" dia. (WH connector)	LF	7.95	8.00	15.95	22.00	(4)	(88)
Gas piping, 1/2"	LF	2.69	5.25	7.94	11.50	(10)	(115)
Gas piping, 1"	LF	3.73	6.25	9.98	14.25	10	143
15-amp circuit, toggle, 40' #14/2 NM	EA	51.00	85.50	136.50	195.00	1	195
GFCI 15-amp, 1-pole breaker	EA	41.99		41.99	46.19	1	46
Total to Builder							**600**
Total to Consumer							**740**

Water Heater option for Electric House: 50 gal Heat Pump Water Heater (HPWH)

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
50 gal electric water heater	EA	419.00		419.00	460.90	(1)	(461)
HPWH, 50 gal, minimum 2.0 EF	EA	1,199.00		1,199.00	1,318.90	1	1,319
Mixing valve	EA	175.00	16.50	191.50	220	1	220
Total to Builder							**1,078**
Total to Consumer							**1,331**

Ventilation Option Gas House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)	EA	88.43		88.43	97.27	(1)	(97)
Bath exhaust fan controller	EA	56.60		56.60	62.26	(1)	(62)
Bath exhaust fan, standard	EA	28.24		28.24	31.06	1	31
Gas furnace, 80 AFUE, multi-speed blower	EA	818.00		818.00	899.80	(1)	(900)
Gas furnace, 80 AFUE, variable-speed blower	EA	1323.00		1323.00	1455.30	1	1,455
ERV, 100 CFM	EA	991.99		991.99	1091.19	1	1,091
HRV/ERV controller	EA	82.99		82.99	91.29	1	91
Installation, labor	HR		39.90	39.90	65.84	2	132
Installation, material	EA	40.00		40.00	44.00	1	44
15-amp circuit, duplex outlet, 20' 14/2 NM	EA	7.30	23.50	30.80	46.00	1	46
Wire, 14/2, add 20'	LF	0.17	1.37	1.54	2.41	20	48
GFCI 15-amp 1-pole breaker	EA	41.99		41.99	46.19	1	46
Grille, exhaust (from house)	EA	35.00	14.50	49.50	62.50	1	63
Duct, flexible insulated, 6" dia	LF	3.81	2.21	6.02	7.85	50	393
Wall cap, 6" dia duct	EA	54.50	29.00	83.50	108.00	2	216
Total to Builder							**2,597**
Total to Consumer							**3,206**

Ventilation Option Electric House

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Bath fan, 90 CFM, EnergyStar (AirKing)	EA	88.43		88.43	97.27	(1)	(97)
Bath exhaust fan controller	EA	56.60		56.60	62.26	(1)	(62)
Bath exhaust fan, standard	EA	28.24		28.24	31.06	1	31
Heat Pump system, multi-speed blower	EA	2394.00		2394.00	2633.40	(1)	(2,633)
Heat Pump system, variable-speed	EA	2828.00		2828.00	3110.80	1	3,111
ERV, 100 CFM	EA	991.99		991.99	1091.19	1	1,091
HRV/ERV controller	EA	82.99		82.99	91.29	1	91
Installation, labor	HR		39.90	39.90	65.84	2	132
Installation, material	EA	40.00		40.00	44.00	1	44
15-amp circuit, duplex outlet, 20' 14/2 NM	EA	7.30	23.50	30.80	46.00	1	46
Wire, 14/2, add 20'	LF	0.17	1.37	1.54	2.41	20	48
GFCI 15-amp 1-pole breaker	EA	41.99		41.99	46.19	1	46
Grille, exhaust (from house)	EA	35.00	14.50	49.50	62.50	1	63
Duct, flexible insulated, 6" dia	LF	3.81	2.21	6.02	7.85	50	393
Wall cap, 6" dia duct	EA	54.50	29.00	83.50	108.00	2	216
Total to Builder							**2,518**
Total to Consumer							**3,109**

Ventilation Option Electric House in CZ 2

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Associated ERV cost to builder from above							2,518
Improve ACH50 from 5 to 3, estimate							1,200
Total to Builder							**3,718**
Total to Consumer							**4,591**

Duct Option: Slab House, Buried Ducts, CZ 2-3

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
R13 duct: add FSK min R5 over R8 duct	SF	0.27	1.70		1.97	3.14	680	2,135
Add ceiling insulation, R49 f.g. blown	SF	0.91	0.76	0.45	2.12	2.73	340	928
Mechanical closet, 3'x4', partition wall	LF	7.40	4.89		12.29	16.15	10	162
Mechanical closet, drywall, finished	SF	0.38	0.61		0.99	1.41	140	197
Mechanical closet door	EA	135.00	34.50		169.50	205.00	1	205
Delete attic platform decking, 3/4, 8'x8'	SF	1.38	0.38		1.76	2.14	(64)	(137)
Delete attic platform joist framing, 2x12	LF	2.53	0.58		3.11	3.73	(40)	(149)
Total to Builder								**3,341**
Total to Consumer								**4,125**

Duct Option: Slab House, Buried Ducts, CZ 4-7

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Add ceiling insulation, R60 f.g. blown	SF	1.13	0.91	0.54	2.58	3.32	340	1,128
Mechanical closet, 3'x4', partition wall	LF	7.40	4.89		12.29	16.15	10	162
Mechanical closet, drywall, finished	SF	0.38	0.61		0.99	1.41	140	197
Mechanical closet door	EA	135.00	34.50		169.50	205.00	1	205
Delete attic platform decking, 3/4, 8'x8'	SF	1.38	0.38		1.76	2.14	(64)	(137)
Delete attic platform joist framing, 2x12	LF	2.53	0.58		3.11	3.73	(40)	(149)
Total to Builder								**1,406**
Total to Consumer								**1,736**

Duct Option: Convert Crawlspace from Vented to Unvented, CZ 3

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Floor insulation, R19	SF	0.60	0.49		1.09	1.46	(1,875)	(2,738)
Wall insulation, foil-faced polyiso, 1", R6	SF	0.81	0.37		1.18	1.50	1000	1,502
Foundation vents	EA	7.98			7.98	8.78	(6)	(53)
Class 1 vapor retarder on ground	SF	0.08	0.08		0.16	0.22	1875	413
Supply duct, 38 cfm (1 cfm/50sf)	EA				125.00	137.50	1	138
Transfer grille	EA	24.00	13.30		37.30	48.50	1	49
Total to Builder								**(690)**
Total to Consumer								**(852)**

Duct Option: Convert Crawlspace from Vented to Unvented, CZ 4

Component	Unit	Material	Labor	Equip	Total	w/O&P	Quantity	Cost
Floor insulation, R19	SF	0.60	0.49		1.09	1.46	(1,875)	(2,738)
Wall insulation, foil-faced polyiso, 2", R12	SF	1.25	0.40		1.65	2.04	1000	2,035
Foundation vents	EA	7.98			7.98	8.78	(6)	(53)
Class 1 vapor retarder on ground	SF	0.08	0.08		0.16	0.22	1875	413
Supply duct, 38 cfm (1 cfm/50sf)	EA				125.00	137.50	1	138
Transfer grille	EA	24.00	13.30		37.30	48.50	1	49
Total to Builder								**(157)**
Total to Consumer								**(193)**

CE40.2

Reference Code Section

R303.1.2 Insulation mark installation

Summary of the Code Change:

This code change adds a new requirement for an insulation certificate to certify the installed R-value of insulation products without an observable manufacturer's R-value mark such as blown-in attic insulation. The certificate must be left by the installer immediately after installation in a conspicuous location within the building.

Cost Implication of the Code Change:

This code change may increase the cost of construction. The analysis is based on the estimated additional time for the installer to complete and post the certificate.

Cost to provide insulation certificate

Component	Unit	Material	Labor	Total	w/O&P	Quantity	Cost
Insulation installer	HR		29.23	29.23	48.23	0.25	12
Total to Builder							**12**
Total to Consumer							**15**

CE151.2

Reference Code Section

R202 Defined terms (new); R403.3.1 Ducts located outside conditioned space

Summary of the Code Change:

This code change adds a definition for Thermal Distribution Efficiency (TDE) and requirements for ducts buried underneath buildings.

Cost Implication of the Code Change:

This code change may decrease the cost of construction in some cases, e.g., where ducts are buried beneath buildings, but this change does not impact cost for the Reference House.

APPENDIX B: CONSTRUCTION COST BY CLIMATE ZONE

Incremental Construction Cost of Individual Code Chage for the Reference House				CZ 2	
				Phoenix	
				Mass (30%)	Frame (70%)
				Electric	Electric
		Affected	Reference	Slab	Slab
Proposal	**Description**	**CZ**	**House**	**100%**	**100%**
RE7	Lighting: revised definition of high-efficacy	All	$0		
RE18/20/21	Certificate: additional info	All	$99	$99	$99
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4-5	$4,970		
RE32	Slab edge: NR to R10/2 (CZ3)	3	$1,988		
"	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$993		
RE33	Ceiling insulation R38 to R49	2-3	$1,366	$1,366	$1,366
RE36	Ceiling insulation R49 to R60	4-7	$1,366		
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA		
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$76		
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0		
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0		
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$13	$13	$13
RE49	Baffles at attic access	All	$12	$12	$12
RE72	Air seal narrow framing cavities	All	$156	$156	$156
RE82	Air seal rim (basement; unvented crawlspace)	All	$1,252		
"	Air seal rim (slab, vented crawlspace)	All	$417	$417	$417
RE96	House tightness, allows trade-off for performance path	All	$0		
RE103	Air seal electrical & communication outlet boxes	All	$369	$369	$369
RE106	Thermostat: requires 7-day programming	All	$0		
RE112	Removes exception for duct test (basement, unvented crawl)	All	$247		
RE130	Adds requirement to test whole-dwelling ventilation	All	$62	$62	$62
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$66	$66	$66
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$3,206		
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$49	$49	$49
"	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$60		
RE148	Lighting, commercial	All	NA		
RE149	Lighting: exterior controls	All	$25	$25	$25
RE151	Performance path backstop: 2009 IECC	All	NA		
RE178	Performance path ventilation type to match proposed	All	NA		
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$15	$15	$15
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA		
	Sub-total without additional efficiency package options			$2,648	$2,648
	Weighted average, foundations				$2,648
			Nat Ave	**CZ 2**	
	Weighted average without additional efficiency package options		5,477	2,648	
RE209	HVAC option		3,824	5,721	
RE209	Water Heater option		1,071	1,331	
RE209	Ventilation option		3,570	4,591	
RE209	Duct option, slab houses		3,074	4,125	
RE209	Duct option, vented crawlspace houses		na		
	Total with HVAC option		9,301	8,369	
	Total with Water Heater option		6,548	3,979	
	Total with Ventilation option		9,047	7,238	
	Total with Duct option, slab houses		8,550	6,773	
	Total with Duct option, vented crawlspace houses		na		

	Incremental Construction Cost of Individual Code Chage for the Reference House			CZ 3 Memphis					
				Mass Wall (10%)			Frame Wall (90%)		
					Electric			Electric	
Proposal	Description	Affected CZ	Reference House	Slab 75%	Basement 10%	Crawl 15%	Slab 75%	Basement 10%	Crawl 15%
RE7	Lighting: revised definition of high-efficacy	All	$0						
RE18/20/21	Certificate: additional info	All	$99	$99	$99	$99	$99	$99	$99
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4-5	$4,970						
RE32	Slab edge: NR to R10/2 (CZ3)	3	$1,988	$1,988			$1,988		
"	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$993						
RE33	Ceiling insulation R38 to R49	2-3	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366
RE36	Ceiling insulation R49 to R60	4-7	$1,366						
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA						
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$76	$76	$76	$76	$76	$76	$76
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0						
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0						
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$13	$13	$13	$13	$13	$13	$13
RE49	Baffles at attic access	All	$12	$12	$12	$12	$12	$12	$12
RE72	Air seal narrow framing cavities	All	$156	$156	$156	$156	$156	$156	$156
RE82	Air seal rim (basement; unvented crawlspace)	All	$1,252		$1,252			$1,252	
"	Air seal rim (slab, vented crawlspace)	All	$417	$417		$417	$417		$417
RE96	House tightness, allows trade-off for performance path	All	$0						
RE103	Air seal electrical & communication outlet boxes	All	$369	$369	$369	$369	$369	$369	$369
RE106	Thermostat: requires 7-day programming	All	$0						
RE112	Removes exception for duct test (basement, unvented crawl)	All	$247		$247			$247	
RE130	Adds requirement to test whole-dwelling ventilation	All	$62	$62	$62	$62	$62	$62	$62
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$66	$66	$66	$66	$66	$66	$66
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$3,206						
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$49	$49			$49		
"	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$60		$60	$60		$60	$60
RE148	Lighting, commercial	All	NA						
RE149	Lighting: exterior controls	All	$25	$25	$25	$25	$25	$25	$25
RE151	Performance path backstop: 2009 IECC	All	NA						
RE178	Performance path ventilation type to match proposed	All	NA						
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$15	$15	$15	$15	$15	$15	$15
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA						
	Sub-total without additional efficiency package options			$4,712	$3,816	$2,735	$4,712	$3,816	$2,735
	Weighted average, foundations					$4,326			$4,326
			Nat Ave	**CZ 3**					
	Weighted average without additional efficiency package options		5,477	4,326					
RE209	HVAC option		3,824	5,721					
RE209	Water Heater option		1,071	1,331					
RE209	Ventilation option		3,570	3,109					
RE209	Duct option, slab houses		3,074	4,125					
RE209	Duct option, vented crawlspace houses		na	(852)					
	Total with HVAC option		9,301	10,047					
	Total with Water Heater option		6,548	5,657					
	Total with Ventilation option		9,047	7,435					
	Total with Duct option, slab houses		8,550	8,451					
	Total with Duct option, vented crawlspace houses		na	3,474					

Proposal	Description	Affected CZ	Reference House	Slab 20%	Basement 60%	Crawl 20%
	Incremental Construction Cost of Individual Code Chage for the Reference House				**CZ 4 Baltimore Frame Wall Gas**	
RE7	Lighting: revised definition of high-efficacy	All	$0			
RE18/20/21	Certificate: additional info	All	$99	$99	$99	$99
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4-5	$4,970	$4,970	$4,970	$4,970
RE32	Slab edge: NR to R10/2 (CZ3)	3	$1,988			
"	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$993	$993		
RE33	Ceiling insulation R38 to R49	2-3	$1,366			
RE36	Ceiling insulation R49 to R60	4-7	$1,366	$1,366	$1,366	$1,366
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA			
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$76	$76	$76	$76
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0			
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0			
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$13	$13	$13	$13
RE49	Baffles at attic access	All	$12	$12	$12	$12
RE72	Air seal narrow framing cavities	All	$156	$156	$156	$156
RE82	Air seal rim (basement; unvented crawlspace)	All	$1,252		$1,252	
"	Air seal rim (slab, vented crawlspace)	All	$417	$417		$417
RE96	House tightness, allows trade-off for performance path	All	$0			
RE103	Air seal electrical & communication outlet boxes	All	$369	$369	$369	$369
RE106	Thermostat: requires 7-day programming	All	$0			
RE112	Removes exception for duct test (basement, unvented crawl)	All	$247		$247	
RE130	Adds requirement to test whole-dwelling ventilation	All	$62	$62	$62	$62
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$66	$66	$66	$66
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$3,206			
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$49	$49		
"	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$60		$60	$60
RE148	Lighting, commercial	All	NA			
RE149	Lighting: exterior controls	All	$25	$25	$25	$25
RE151	Performance path backstop: 2009 IECC	All	NA			
RE178	Performance path ventilation type to match proposed	All	NA			
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$15	$15	$15	$15
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA			
	Sub-total without additional efficiency package options			$8,686	$8,786	$7,705
	Weighted average, foundations					$8,550
			Nat Ave		**CZ 4**	
	Weighted average without additional efficiency package options		5,477		8,550	
RE209	HVAC option		3,824		1,317	
RE209	Water Heater option		1,071		740	
RE209	Ventilation option		3,570		3,206	
RE209	Duct option, slab houses		3,074		1,736	
RE209	Duct option, vented crawlspace houses		na		(193)	
	Total with HVAC option		9,301		9,867	
	Total with Water Heater option		6,548		9,290	
	Total with Ventilation option		9,047		11,755	
	Total with Duct option, slab houses		8,550		10,286	
	Total with Duct option, vented crawlspace houses		na		8,356	

Proposal	Description	Affected CZ	Reference House	Slab 15%	Frame Wall Gas (60%) Basement 70%	Crawl 15%	Slab 15%	Frame Wall Electric (40%) Basement 70%	Crawl 15%
Incremental Construction Cost of Individual Code Chage for the Reference House					**CZ 5 Chicago**				
RE7	Lighting: revised definition of high-efficacy	All	$0						
RE18/20/21	Certificate: additional info	All	$99	$99	$99	$99	$99	$99	$99
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4-5	$4,970	$4,970	$4,970	$4,970	$4,970	$4,970	$4,970
RE32	Slab edge: NR to R10/2 (CZ3)	3	$1,988						
"	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$993	$993			$993		
RE33	Ceiling insulation R38 to R49	2-3	$1,366						
RE36	Ceiling insulation R49 to R60	4-7	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA						
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$76						
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0						
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0						
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$13	$13	$13	$13	$13	$13	$13
RE49	Baffles at attic access	All	$12	$12	$12	$12	$12	$12	$12
RE72	Air seal narrow framing cavities	All	$156	$156	$156	$156	$156	$156	$156
RE82	Air seal rim (basement; unvented crawlspace)	All	$1,252		$1,252	$1,252		$1,252	$1,252
"	Air seal rim (slab, vented crawlspace)	All	$417	$417			$417		
RE96	House tightness, allows trade-off for performance path	All	$0						
RE103	Air seal electrical & communication outlet boxes	All	$369	$369	$369	$369	$369	$369	$369
RE106	Thermostat: requires 7-day programming	All	$0						
RE112	Removes exception for duct test (basement, unvented crawl)	All	$247		$247	$247		$247	$247
RE130	Adds requirement to test whole-dwelling ventilation	All	$62	$62	$62	$62	$62	$62	$62
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$66	$66	$66	$66	$66	$66	$66
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$3,206						
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$49	$49			$49		
"	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$60		$60	$60		$60	$60
RE148	Lighting, commercial	All	NA						
RE149	Lighting: exterior controls	All	$25	$25	$25	$25	$25	$25	$25
RE151	Performance path backstop: 2009 IECC	All	NA						
RE178	Performance path ventilation type to match proposed	All	NA						
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$15	$15	$15	$15	$15	$15	$15
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA						
	Sub-total without additional efficiency package options			$8,610	$8,710	$8,710	$8,610	$8,710	$8,710
	Weighted average, foundations					$8,695			$8,695
			Nat Ave		**CZ 5 Gas**			**CZ 5 Electric**	
	Weighted average without additional efficiency package options		5,477		8,695			8,695	
RE209	HVAC option		3,824		1,494			8,196	
RE209	Water Heater option		1,071		740			2,503	
RE209	Ventilation option		3,570		3,206			3,109	
RE209	Duct option, slab houses		3,074		1,736			1,736	
RE209	Duct option, vented crawlspace houses		na						
	Total with HVAC option		9,301		10,188			16,890	
	Total with Water Heater option		6,548		9,435			11,198	
	Total with Ventilation option		9,047		11,900			11,804	
	Total with Duct option, slab houses		8,550		10,431			10,431	
	Total with Duct option, vented crawlspace houses		na						

Incremental Construction Cost of Individual Code Chage for the Reference House					CZ 6 Helena Frame Wall Gas			CZ 7 Duluth Frame Wall Gas	
Proposal	Description	Affected CZ	Reference House	Slab 5%	Basement 90%	Crawl 5%	Slab 30%	Basement 5%	Crawl 65%
RE7	Lighting: revised definition of high-efficacy	All	$0						
RE18/20/21	Certificate: additional info	All	$99	$99	$99	$99	$99	$99	$99
RE29	Frame wall, c.i.: R5 to R10 (2x4); R0 to R5 (2x6)	4-5	$4,970						
RE32	Slab edge: NR to R10/2 (CZ3)	3	$1,988						
"	Slab edge: R10/2 to R10/4 (CZ4-5)	4-5	$993						
RE33	Ceiling insulation R38 to R49	2-3	$1,366						
RE36	Ceiling insulation R49 to R60	4-7	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366	$1,366
RE34	Floors, removes exception for min R19 if fills cavity	5-8	NA						
RE35	Windows: reduces U-value from 0.32 to 0.30	3-4	$76						
RE37	Windows: changes SHGC form NR to 0.40	5 & 4C	$0						
RE105	Windows: reduces max SHGC tradeoff from 0.50 to 0.40	2-3	$0						
RE46	Attic access hatch: no direct cost; cost of additional insulation	All	$13	$13	$13	$13	$13	$13	$13
RE49	Baffles at attic access	All	$12	$12	$12	$12	$12	$12	$12
RE72	Air seal narrow framing cavities	All	$156	$156	$156	$156	$156	$156	$156
RE82	Air seal rim (basement; unvented crawlspace)	All	$1,252		$1,252	$1,252		$1,252	$1,252
"	Air seal rim (slab, vented crawlspace)	All	$417	$417			$417		
RE96	House tightness, allows trade-off for performance path	All	$0						
RE103	Air seal electrical & communication outlet boxes	All	$369	$369	$369	$369	$369	$369	$369
RE106	Thermostat: requires 7-day programming	All	$0						
RE112	Removes exception for duct test (basement, unvented crawl)	All	$247		$247	$247		$247	$247
RE130	Adds requirement to test whole-dwelling ventilation	All	$62	$62	$62	$62	$62	$62	$62
RE133	Updates ventilation fan efficacy (affects bath EF)	All	$66	$66	$66	$66	$66	$66	$66
RE139	Requires ERV/HRV in CZ 7-8 (includes RE134 air handler integration)	7	$3,206				$3,206	$3,206	$3,206
RE145	Lighting: 100% high-efficacy; controls (slab)	All	$49	$49			$49		
"	Lighting: 100% high-efficacy; controls (basement, crawl)	All	$60		$60	$60		$60	$60
RE148	Lighting, commercial	All	NA						
RE149	Lighting: exterior controls	All	$25	$25	$25	$25	$25	$25	$25
RE151	Performance path backstop: 2009 IECC	All	NA						
RE178	Performance path ventilation type to match proposed	All	NA						
CE40.2	Insulation certificate if no manufacturer mark (i.e., blown)	All	$15	$15	$15	$15	$15	$15	$15
CE151.2	Defines duct TDE; adds requirements for underground ducts	All	NA						
	Sub-total without additional efficiency package options			$2,648	$3,740	$3,740	$5,853	$6,946	$6,946
	Weighted average, foundations					$3,685			$6,618
			Nat Ave		**CZ 6**			**CZ 7**	
	Weighted average without additional efficiency package options		5,477		3,685			6,618	
RE209	HVAC option		3,824		1,494			1,494	
RE209	Water Heater option		1,071		740			740	
RE209	Ventilation option		3,570		3,206			0	
RE209	Duct option, slab houses		3,074		1,736			1,736	
RE209	Duct option, vented crawlspace houses		na						
	Total with HVAC option		9,301		5,179			8,112	
	Total with Water Heater option		6,548		4,426			7,358	
	Total with Ventilation option		9,047		6,891			6,618	
	Total with Duct option, slab houses		8,550		5,421			8,354	
	Total with Duct option, vented crawlspace houses		na						

APPENDIX C: LOCATION ADJUSTMENT FACTORS

State	City	Cost Adjustment Factor	State	City	Cost Adjustment Factor
Alabama	Birmingham	0.84	Montana	Billings	0.89
Alabama	Mobile	0.83	Nebraska	Omaha	0.90
Alaska	Fairbanks	1.21	Nevada	Las Vegas	1.03
Arizona	Phoenix	0.84	New Hampshire	Portsmouth	0.95
Arizona	Tucson	0.84	New Jersey	Jersey City	1.18
Arkansas	Little Rock	0.83	New Mexico	Albuquerque	0.86
California	Alhambra	1.15	New York	Long Island City	1.36
California	Los Angeles	1.15	New York	Syracuse	0.99
California	Riverside	1.13	North Carolina	Charlotte	0.99
California	Stockton	1.20	North Carolina	Hickory	0.93
Colorado	Boulder	0.90	North Carolina	Raleigh	0.94
Colorado	Colorado Springs	0.87	North Dakota	Fargo	0.87
Colorado	Denver	0.91	Ohio	Columbus	0.91
Connecticut	New Haven	1.10	Oklahoma	Oklahoma City	0.84
Delaware	Dover	1.02	Oklahoma	Tulsa	0.83
District of Columbia	Washington, D.C.	0.92	Oregon	Bend	1.02
Florida	Fort Meyers	0.79	Pennsylvania	Norristown	1.05
Florida	Miami	0.83	Pennsylvania	State College	0.94
Florida	Orlando	0.82	Rhode Island	Providence	1.09
Florida	Tampa	0.81	South Carolina	Greenville	0.97
Georgia	Atlanta	0.90	South Dakota	Sioux Falls	0.92
Hawaii	Honolulu	1.22	Tennessee	Memphis	0.87
Idaho	Boise	0.89	Texas	Austin	0.80
Illinois	Chicago	1.25	Texas	Dallas	0.84
Indiana	Indianapolis	0.92	Texas	Houston	0.84
Iowa	Des Moines	0.92	Texas	San Antonio	0.83
Kansas	Wichita	0.81	Utah	Ogden	0.84
Kentucky	Louisville	0.89	Utah	Provo	0.85
Louisiana	Baton Rouge	0.85	Utah	Salt Lake City	0.85
Maine	Portland	0.94	Vermont	Burlington	0.95
Maryland	Baltimore	0.93	Virginia	Fairfax	1.00
Massachusetts	Boston	1.18	Virginia	Winchester	0.99
Michigan	Ann Arbor	0.99	Washington	Tacoma	1.05
Minnesota	Minneapolis	1.09	West Virginia	Charleston	0.94
Mississippi	Biloxi	0.83	Wisconsin	La Crosse	0.95
Missouri	Springfield	0.86	Wyoming	Casper	0.85
*Source: RSMeans *Residential Cost Data 2021*. Sample cities are listed in this table; check RSMeans for additional locations.					

APPENDIX D: 2021 IECC INSULATION AND FENESTRATION CHANGES

The table below shows the insulation and fenestration requirements for the 2018 IECC and 2021 IECC. For comparison purposes, the 2021 IECC values are shown only where those have been changed from the 2018 values.

Insulation and Fenestration Requirements. Source: adapted from the 2018 and 2021 IECC.

	CZ 2		CZ 3		CZ 4 except 4C		CZ 5 and 4C		CZ 6		CZ 7	
	Phoenix		Memphis		Baltimore		Chicago		Helena		Duluth	
Component	**2018**	**2021**	**2018**	**2021**	**2018**	**2021**	**2018**	**2021**	**2018**	**2021**	**2018**	**2021**
Fenestration U-factor	0.40		0.32	0.30	0.32	0.30	0.30		0.30		0.30	
Fenestration SHGC	0.25		0.25		0.4		NR	0.40	NR		NR	
Skylight U-factor	0.65		0.55		0.55		0.55		0.55		0.55	
Ceiling R-value	38	49	38	49	49	60	49	60	49	60	49	60
Frame Wall R-value (selected for modeling)	13		13+5		13+5	13+10	13+5	13+10	13+10		13+10	
Mass Wall R-value (<half/>half on interior	4/6		8/13		8/13		13/17		15/20		19/21	
Floor R-value	13		19		19		30		30		38	
Basement wall R-value, ci/cavity	0		5/13		10/13		15/19		15/19		15/19	
Slab R-value/depth	0		0	10/2	10/2	10/4	10/2	10/4	10/4		10/4	
Crawl wall R-value, ci/cavity	0		5/13		10/13		15/19		15/19		15/19	

APPENDIX E: ENERGY USE BY CLIMATE ZONE

Configuration		Annual Energy Use CZ 2 Phoenix Mass Wall (30%) Electric kWh/yr	$/yr	Savings*	Frame Wall (70%) Electric kWh/yr	$/yr	Savings*
2018 Baseline	Slab	17,107	2,225		17,087	2,223	
	Basement						
	Crawl**						
2018 + 2021 ceiling insulation	Slab	17,052	2,218	0.3%	17,028	2,215	0.4%
	Basement						
	Crawl**						
2018 + 2021 slab insulation	Slab						
	Ave for CZ						
2018 + 2021 wall cont. insulation	Slab						
	Basement						
	Crawl**						
2018 + 2021 window U-Factor	Slab						
	Basement						
	Crawl**						
2021 without efficiency options	Slab	16,638	2,164	2.7%	16,615	2,162	2.7%
	Basement						
	Crawl**						
2021 + HVAC option	Slab	15,727	2,046	8.0%	15,715	2,045	8.0%
	Basement						
	Crawl**						
2021 + Water Heater option	Slab	15,618	2,030	8.8%	15,589	2,027	8.8%
	Basement						
	Crawl**						
2021 + Ventilation option	Slab	16,506	2,147	3.5%	16,465	2,142	3.6%
	Basement						
	Crawl**						
2021 + Duct option	Slab	15,768	2,051	7.8%	15,715	2,044	8.1%
	Crawl**						
*Cost savings ($/yr) relative to 2018 baseline							
**Crawl: vented CZ 3-4; conditioned CZ 5-7							

Configuration		Annual Energy Use CZ 3 Memphis Mass Wall (10%) Electric kWh/yr	$/yr	Savings*	Frame Wall (90%) Electric kWh/yr	$/yr	Savings*
2018 Baseline	Slab	15618	2031		15,557	2,023	
	Basement	16612	2161		16547	2152	
	Crawl**	15144	1970		15056	1958	
2018 + 2021 ceiling insulation	Slab	15536	2021	0.5%	15,472	2,012	0.5%
	Basement	16521	2149	0.6%	16,451	2,140	0.6%
	Crawl**	15053	1958	0.6%	14,959	1,946	0.6%
2018 + 2021 slab insulation	Slab	14938	1943	4.3%	14,877	1,935	4.3%
	Ave for CZ					1,936	
2018 + 2021 wall cont. insulation	Slab						
	Basement						
	Crawl**						
2018 + 2021 window U-Factor	Slab	15566	2024	0.3%	15,501	2,016	0.3%
	Basement	16553	2154	0.3%	16,489	2,145	0.3%
	Crawl**	15091	1963	0.4%	14,994	1,951	0.4%
2021 without efficiency options	Slab	14,408	1,874	7.7%	14,344	1,866	7.8%
	Basement	15,903	2,068	4.3%	15,832	2,059	4.3%
	Crawl**	14,610	1,900	3.6%	14,519	1,889	3.5%
2021 + HVAC option	Slab	13,485	1,754	13.6%	13,450	1,749	13.5%
	Basement	14,824	1,928	10.8%	14,786	1,924	10.6%
	Crawl**	13,561	1,765	10.4%	13,502	1,756	10.3%
2021 + Water Heater option	Slab	13,277	1,726	15.0%	13,212	1,718	15.1%
	Basement	14,742	1,916	11.3%	14,669	1,907	11.4%
	Crawl**	13,470	1,752	11.1%	13,382	1,740	11.1%
2021 + Ventilation option	Slab	14,326	1,864	8.2%	14,259	1,855	8.3%
	Basement	15,727	2,046	5.3%	15,651	2,036	5.4%
	Crawl**	14,446	1,879	4.6%	14,346	1,867	4.6%
2021 + Duct option	Slab	13,816	1,797	11.5%	13,749	1,788	11.6%
	Crawl**	14,273	1,857	5.7%	14,174	1,844	5.8%
*Cost savings ($/yr) relative to 2018 baseline							
**Crawl: vented CZ 3-4; conditioned CZ 5-7							

Configuration		Annual Energy Use CZ 4 Baltimore Frame Wall Natural Gas kWh/yr	thrm/yr	$/yr	Savings*
2018 Baseline	Slab	8,262	697	1,807	
	Basement	9,848	696	2,012	
	Crawl**	8,669	665	1,826	
2018 + 2021 ceiling insulation	Slab	8,244	690	1,797	0.6%
	Basement	9,833	689	2,003	0.4%
	Crawl**	8,652	659	1,818	0.4%
2018 + 2021 slab insulation	Slab	8,180	674	1,772	1.9%
	Ave for CZ			1,772	
2018 + 2021 wall cont. insulation	Slab	8,177	661	1,758	2.7%
	Basement	9,763	660	1,964	2.4%
	Crawl**	8,590	629	1,778	2.6%
2018 + 2021 window U-Factor	Slab	8,256	687	1,796	0.6%
	Basement	9,848	686	2,002	0.5%
	Crawl**	8,666	656	1,816	0.5%
2021 without efficiency options	Slab	7,673	626	1,655	8.4%
	Basement	9,159	649	1,873	6.9%
	Crawl**	8,174	616	1,711	6.3%
2021 + HVAC option	Slab	7,348	565	1,550	14.2%
	Basement	8,795	580	1,753	12.9%
	Crawl**	7,761	552	1,590	12.9%
2021 + Water Heater option	Slab	7,670	604	1,624	10.1%
	Basement	9,188	617	1,835	8.8%
	Crawl**	8,171	594	1,678	8.1%
2021 + Ventilation option	Slab	7,931	586	1,648	8.8%
	Basement	9,481	584	1,847	8.2%
	Crawl**	8,420	575	1,700	6.9%
2021 + Duct option	Slab	7,495	581	1,585	12.3%
	Crawl**	7,732	607	1,644	10.0%
*Cost savings ($/yr) relative to 2018 baseline					
**Crawl: vented CZ 3-4; conditioned CZ 5-7					

Configuration		kWh/yr	Annual Energy Use CZ 5 Chicago Frame Wall Natural Gas (60%) thrm/yr	$/yr	Savings*
2018 Baseline	Slab	7635	1098	2156	
	Basement	9,297	1,089	2,355	
	Crawl**	7,720	999	2,054	
2018 + 2021 ceiling insulation	Slab	7,691	1,090	2,146	0.5%
	Basement	9,285	1,080	2,343	0.5%
	Crawl**	7,702	991	2,043	0.5%
2018 + 2021 slab insulation	Slab	7,647	1,071	2,120	1.7%
	Ave for CZ				
2018 + 2021 wall cont. insulation	Slab	7,617	1,049	2,093	2.9%
	Basement	9,209	1,040	2,291	2.7%
	Crawl**	7,635	952	1,993	3.0%
2018 + 2021 window U-Factor	Slab				
	Basement				
	Crawl**				
2021 without efficiency options	Slab	7,142	1,018	1,999	7.3%
	Basement	8,614	1,037	2,210	6.2%
	Crawl**	7,216	947	1,934	5.8%
2021 + HVAC option	Slab	6,770	898	1,824	15.4%
	Basement	8,209	914	2,029	13.8%
	Crawl**	6,838	837	1,769	13.9%
2021 + Water Heater option	Slab	7,169	1,002	1,977	8.3%
	Basement	8,655	1,007	2,175	7.6%
	Crawl**	7,245	929	1,910	7.0%
2021 + Ventilation option	Slab	7,400	966	1,978	8.3%
	Basement	8,927	960	2,170	7.9%
	Crawl**	7,482	901	1,921	6.5%
2021 + Duct option	Slab	7,022	929	1,889	12.4%
	Crawl**				
*Cost savings ($/yr) relative to 2018 baseline					
**Crawl: vented CZ 3-4; conditioned CZ 5-7					

Configuration		Annual Energy Use CZ 6 Helena Frame Wall Natural Gas kWh/yr	thrm/yr	$/yr	Savings*	Annual Energy Use CZ 7 Duluth*** Frame Wall Natural Gas kWh/yr	thrm/yr	$/yr	Savings*
2018 Baseline	Slab	7,374	1,201	2,221		7,178	1,676	2,735	
	Basement	8,962	1,166	2,391		8,664	1,612	2,873	
	Crawl**	7,345	1,057	2,066		7,119	1,473	2,515	
2018 + 2021 ceiling insulation	Slab	7,359	1,192	2,210	0.5%	7,116	1,665	2,722	0.5%
	Basement	8,945	1,155	2,378	0.5%	8,649	1,599	2,857	0.6%
	Crawl**	7,333	1,047	2,054	0.6%	7,105	1,460	2,499	0.6%
2018 + 2021 slab insulation	Slab								
	Ave for CZ								
2018 + 2021 wall cont. insulation	Slab								
	Basement								
	Crawl**								
						CZ 7 2021 no HRV, for reference:			
2018 + 2021 window U-Factor	Slab					7,087	1,671	2,678	2.1%
	Basement					8,479	1,607	2,791	2.9%
	Crawl**					7,028	1,466	2,454	2.4%
2021 without efficiency options	Slab	6,970	1,198	2,165	2.5%	7,321	1,605	2,639	3.5%
	Basement	8,379	1,162	2,311	3.3%	8,787	1,523	2,743	4.5%
	Crawl**	6,937	1,052	2,008	2.8%	7,283	1,419	2,438	3.1%
2021 + HVAC option	Slab	6,586	1,054	1,964	11.6%	6,879	1,403	2,369	13.4%
	Basement	7,984	1,024	2,115	11.5%	8,344	1,333	2,486	13.5%
	Crawl**	6,583	930	1,833	11.3%	6,870	1,244	2,201	12.5%
2021 + Water Heater option	Slab	7,037	1,188	2,155	3.0%	7,400	1,600	2,635	3.7%
	Basement	8,441	1,135	2,282	4.6%	8,854	1,499	2,718	5.4%
	Crawl**	7,005	1,038	1,993	3.5%	7,353	1,409	2,429	3.4%
						CZ 7 2021 HRV .75 SRE v. .65:			
2021 + Ventilation option	Slab	7,198	1,126	2,120	4.5%	7,307	1,588	2,619	4.2%
	Basement	8,672	1,068	2,250	5.9%	8,772	1,502	2,719	5.4%
	Crawl**	7,189	995	1,980	4.2%	7,271	1,403	2,420	3.8%
2021 + Duct option	Slab	6,832	1,043	1,985	10.6%	7,210	1,409	2,418	11.6%
	Crawl**								
*Cost savings ($/yr) relative to 2018 baseline									
**Crawl: vented CZ 3-4; conditioned CZ 5-7									
***For CZ 7 all 2021 results include an HRV									

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EXHIBIT 5

Comparison of 2021 IECC Residential Cost Effectiveness Analyses

This document is intended to provide a comparison of two reports the *2021 IECC Residential Cost Effectiveness Analysis* published for the National Association of Homebuilders (NAHB) by Home Innovation Research Labs (HIRL) in June 2021, hereafter referred to as the HIRL report[1]; and the report of the same name published by ICF in January 2022, hereafter referred to as the ICF report. The purpose of this document is to identify concerns and issues in the HIRL report, which were addressed in the ICF report.

Simplistic Economic Metrics

The HIRL report only evaluates cost effectiveness using a simple payback metric, which is easy to calculate and understand, however it is not appropriate to use for evaluating energy code changes. The U.S. Department of Energy's *Methodology for Evaluating Cost Effectiveness of Residential Energy Code Changes* (DOE Methodology)[2] concludes that "because simple payback ignores many of the longer-term factors in the economic performance of an energy-efficiency investment, DOE does not use [simple payback] as a primary indicator of cost effectiveness for its own decision-making purposes."

Instead, the DOE Methodology uses Life-Cycle Cost (LCC) as the primary metric to evaluate cost effectiveness, therefore the ICF report also uses this metric.

High Builder Profit Margins

The HIRL report stated that the total cost to the consumer included a builder's gross profit margin of 19%. Several issues were found with this, all leading to higher costs which would negatively impact cost effectiveness.

First, many code changes in Appendix A of the HIRL report were found to have a higher profit margin applied. For example, RE112 had a reported cost to the builder of $200 and a cost to the consumer of $247, which would be a profit margin of 24%.

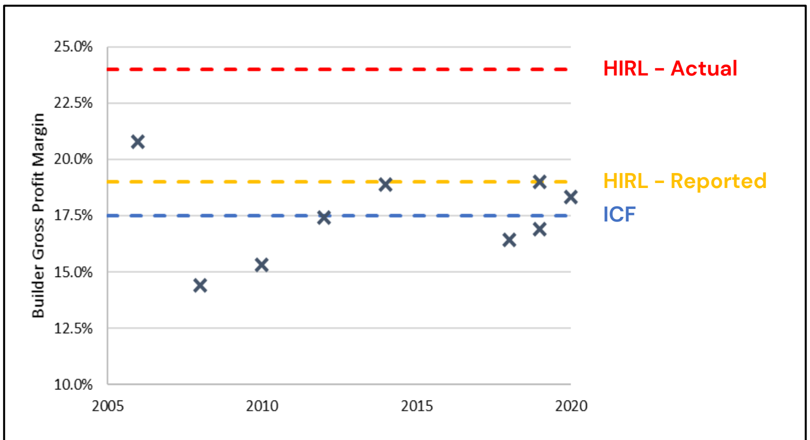

Figure 1: Comparison of Builder Gross Profit Margin

Additionally, the ICF report considered changes in builder profit margins over time and used an average value representing all data that was available. In figure 1, the data available for builder gross profit margin is shown by black X's, with their average – the value used in the ICF report - shown by the blue line. The profit margin used in the ICF report is a more representative value, as the value reported to have been used in the HIRL report is the highest profit margin seen since 2006, and the value that was actually used is higher than any reported historical profit margin.

Finally, the HIRL report assumed all construction was performed by subcontractors, so the excessively high profit margin of 24% was applied twice, once reflecting the subcontractor's profit and again to reflect the builder's profit. To reflect that the majority, but not all, aspects of homebuilding are subcontracted, the ICF report applied a factor of 79.3% to subcontractor markups to reflect the average share of construction costs that are subcontracted dating back to 2012.[3]

1 Source: https://www.nahb.org/-/media/NAHB/advocacy/docs/top-priorities/codes/code-adoption/2021-iecc-cost-effectiveness-analysis-hirl.pdf
2 Source: https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf
3 Source: https://www.nahb.org/-/media/NAHB/news-and-economics/docs/housing-economics-plus/special-studies/2020/special-study-average-new-home-uses-24-different-subcontractors.pdf

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General High Cost

When reviewing the HIRL report, the high estimated incremental cost of code changes conflicted with other data sources, specifically Northwest national Laboratory's (PNNL's) *National Cost Effectiveness of the Residential Provisions of the 2021 IECC*, as shown in Figure 2.[4] After reviewing and updating cost data, the ICF report concluded costs were generally in line with the PNNL report, instead of 2 to 3 times higher as shown in the HIRL report.

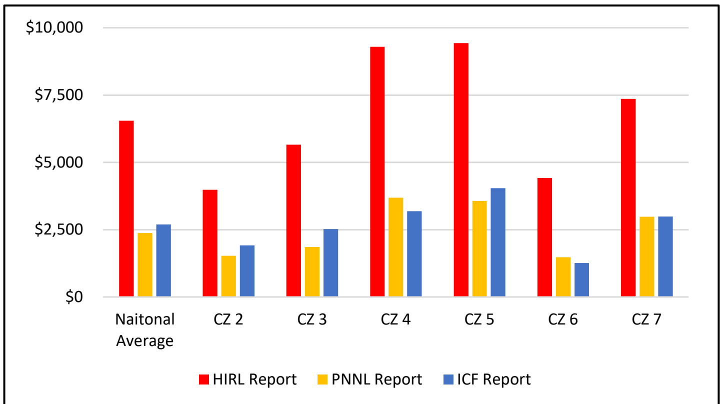

Figure 2: Comparison of 2021 IECC Code Change Costs

Costs for Negligible Administrative Changes

Some code changes in the 2021 IECC are administrative and technically are new requirements, but in practice require no, or negligible, incremental cost. They simply require reporting readily available information (e.g., RE18, 20, 21, CE40.2). The HIRL report included a cost of $114 for these code changes for every home, which was considered inaccurate and removed in the ICF report.

Costs Included for Code Changes that Save Energy but Not Modeled

Some code changes result in energy savings but were not able to be modeled due to limitations in energy modeling software. Therefore, energy savings for these changes are not included. Despite this limitation the HIRL report included costs for these code changes leading to an inaccurate accounting of costs and calculation of cost-effectiveness. These code changes include RE149 Lighting: exterior controls, and RE49 Baffles at attic access.

Outlier Energy Savings Estimates

Savings from the HIRL report and PNNL's savings estimates (*Energy Savings Analysis: 2021 IECC for Residential Buildings*[5]), were compared and national average savings were comparable (9.7% for HIRL and 8.7% for PNNL). However, some results in specific climate zones showed significant differences as shown in Figure 3 (i.e., climate zones 3 and 7). Due to the robustness of the methodology that PNNL's savings estimates used, it is likely that there is an issue with the modeled energy use in the HIRL report. However, this cannot be confirmed, nor could the potential impact on the cost-effectiveness be determined.

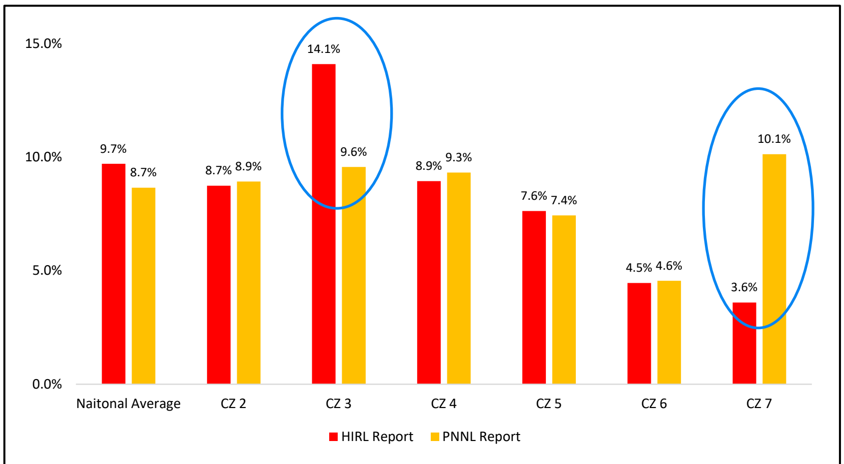

Figure 3: Comparison of Energy Cost Savings

Weighting Factors & Permutations

The HIRL report relies on a methodology developed in 2012 for the National Association of Homebuilders.[6] This methodology is notably simpler than the DOE methodology, last updated in 2015 based on a public process where stakeholders can submit comments on the methodology.[7] The methodology used in the

[4] Source: https://www.energycodes.gov/sites/default/files/2021-07/2021IECC_CostEffectiveness_Final_Residential.pdf
[5] Source: https://www.energycodes.gov/sites/default/files/2021-07/2021_IECC_Final_Determination_AnalysisTSD.pdf
[6] Source: https://www.nahb.org/-/media/NAHB/advocacy/docs/top-priorities/codes/codes-and-research/calculation-methodology.PDF
[7] Source: https://www.regulations.gov/docket/EERE-2015-BT-BC-0001

HIRL report has not been publicly vetted. It utilizes a smaller number of foundation types, fuel types, and locations than DOE uses to assess codes and leads to a less complete picture of the impacts of code changes.

The HIRL report also relies on weighting factors that differ from the DOE methodology. For example, the HIRL report uses data from the 2019 Annual Builder Performance Survey (ABPS) of approximately 1,500 home builders to estimate the amount of construction in each climate zone. The DOE methodology relies on the U.S. Census Builder Permits Survey which gathers permit data from over 20,000 permit offices. the Census data provides a larger statistical sample and presumably the better source for establishing weighted national averages.

Annual Energy Use / Costs Errors

Appendix E in the HIRL report presents annual energy use and costs for 153 modeled homes, 19 of which were identified as having a significant error where the reported energy use and energy rates did not result in the documented energy costs. See below for an example of the climate zone 7, crawlspace, 2018 IECC home which results in a discrepancy of over $40.

Reported Energy Use	Reported Energy Rates	Calculated Energy Cost	Reported Energy Cost
7,119 kWh 1,473 therms	$0.1301 / kWh $1.051 / therm	$2,474 (7,119 x 0.1301 + 1,473 x 1.051)	$2,515

To correct this issue, the ICF report applied a factor to correct the energy use to result in the reported energy cost. The reported energy cost could not have been used directly because the ICF report used a more robust economic metric which accounts for changes in future energy prices.

Dimmer Quantity Error

RE145 changes lighting requirements and adds lighting controls except for bathrooms, hallways, exterior lighting fixtures, and lighting designed for safety or security. The HIRL report includes a cost for a dimmer in a crawlspace, which would be an exempted for safety purposes. Including the crawlspace dimmer cost overstates the cost of the code change and negatively impacts cost-effectiveness, so the cost was removed in the ICF report.

Duct Option Analysis Omits Some Foundation Types

The HIRL report only considered slab and crawlspace homes for the more efficient thermal distribution system option (from RE209). This option could be used for any home and should have been evaluated for more foundation types (e.g., basements) to offer a complete picture of the savings and cost-effectiveness. For some foundation types, like conditioned basements, it is likely that ducts were already located in conditioned space before the 2021 IECC so there would be no change in requirements resulting from this code change.

Misleading Cost Effectiveness of Additional Efficiency Package Options

Table 21 in the HIRL report makes a misleading comparison of the cost-effectiveness of the additional efficiency package options against a baseline of the 2021 IECC (without the options). This is an odd comparison because the options, combined with the other code changes of the 2021 IECC, achieve savings against the 2018 IECC. Therefore the 2018 IECC would have been a more appropriate baseline and would show more savings and better cost-effectiveness. The table could be useful to make a comparison of which option is relatively more cost-effective, but should not be used to determine if these options are cost effective or not.

EXHIBIT 6

Economic Analysis of Proposed Residential Code Amendments

February 2022

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Executive Summary

This analysis examines the cost of adopting the 2021 International Energy Conservation Code (IECC) combined with three additional amendments (all-electric codes, increased air sealing with added mechanical ventilation, and increased wall insulation) compared to the current 2015 Michigan code over a 7-year time period. We completed this analysis in each of Michigan's three Climate Zones (5, 6, and 7) to capture the varying cost impacts across the state. This analysis meets the requirements of the Stille-Derossett-Hale Single State Construction Code Act.[1]

The amendments analyzed in this study are a subsection of the amendments submitted by members of the Michigan Building Decarbonization Coalition. The additional amendments not fully discussed in this analysis include:

- Electric Vehicle-Readiness
- Solar Photovoltaic-Readiness
- Battery Storage-Readiness
- Demand Response Water Heaters
- Electric-Readiness

For more discussion of these additional amendments and how they reduce costs over the lifetime of the building, see Appendix A.

Our results report that single-family detached residential homes built to all-electric 2021 IECC and all-electric 2021 IECC with increased wall insulation and air sealing are cost-neutral over 7 years compared to the current code in Climate Zones 5 and 6. This indicates that these scenarios will not significantly impact costs for Michigan homeowners while immediately improving indoor air quality, increasing comfort and safety, and improving energy efficiency. Over the lifetime of the building, these scenarios will reduce the likelihood of expensive moisture problems, improve outdoor air quality, and reduce climate emissions. This analysis finds that the proposed all-electric code scenarios reduce upfront costs by up to $2,000 in all climate zones because they avoid the costs associated with installation of gas (commonly referred to as natural gas) infrastructure. Additionally, the monthly operational costs and 7-year life cycle costs of the all-electric code scenarios are cost competitive with the current Michigan building code in Climate Zones 5 and 6. This analysis shows that Climate Zone 7 is not cost-effective with an all-electric code requirement, however the cost-effectiveness can be improved with high performance cold climate heat pumps and heat pump friendly electric rate structures which this analysis did not include.

The cost savings persist despite taking a conservative approach to this analysis consistent with the Department of Energy (DOE) building code cost assessment methodology and the Stille-Derossett-Hale requirements. The analysis of the all-electric scenarios used standard efficiency heat pumps that complied with code minimums of the 2021 IECC. However, energy savings can be larger than illustrated in this analysis if buildings use commercially available high-performance cold climate heat pumps. Furthermore, we assume gas prices only increase by inflation to comply with Michigan law, but historically, the volatility of gas prices has significantly exceeded that of electricity prices. Just this winter, gas prices are expected to rise by ~46% compared to last winter in the Midwest, whereas electricity prices are only expected to rise by 3%.[2] Utility bill uncertainty is especially harmful to low-income customers who spend a larger portion

[1] http://www.legislature.mi.gov/documents/mcl/pdf/mcl-act-230-of-1972.pdf
[2] https://www.eia.gov/outlooks/steo/special/winter/2021_Winter_Fuels.pdf

of their salary on utility costs compared to the average residents in the region[3]. The impact of gas cost volatility is not reflected in this analysis. We also implement standard electric rate designs, but some Michigan utilities provide electric rate structures that better support all-electric buildings and operational savings. For example, the three electric utilities used in this analysis (DTE, Consumers, and UPPCO) have either heating service or time of use rates that could help all-electric homeowners decrease their utility bills. Furthermore, we do not account for the ~30% of consumers using propane in Climate Zone 7.[4] Propane fuel is about two to three times more expensive than natural gas, making electric appliances an even more attractive option compared to combustion appliances.[5] Studies show that on average, propane customers would save $564/year in utility bills if instead they used a high-efficiency all-electric heat pump.[6] Finally, we do not include any rebates for energy efficient appliances which would decrease upfront costs for homeowners. **Because of these conservative assumptions, this analysis could be under reporting the cost effectiveness of the proposed all-electric scenarios.**

After reviewing the results of this analysis, we recommend that all-electric 2021 IECC with improved air sealing, increased wall insulation, and mechanical ventilation be adopted in Climate Zones 5 and 6. In Climate Zone 7, we recommend that the Construction Codes Commission adopt electric-ready 2021 IECC with improved air sealing, increased wall insulation, and mechanical ventilation. The proposed scenarios are cost competitive with the current code and deliver necessary health and safety improvements to Michigan homes. Michigan's Construction Code Commission can ensure residents have healthy, safe, and affordable new homes by adopting the proposed amendments.

[3] https://www.aceee.org/sites/default/files/pdfs/u2006.pdf
[4] https://epa.maps.arcgis.com/apps/webappviewer/index.html?id=044e6d58b4f045bf9059cba0a76d059b
[5] https://www.eia.gov/outlooks/steo/special/winter/2021_Winter_Fuels.pdf
[6] https://map.rewiringamerica.org/states/michigan-mi

Background

This analysis examines the cost of adopting the 2021 IECC with three additional amendments compared to the current 2015 Michigan code. The proposed amendments are as follows:

- **Amendment 1:** Require new residential homes to be all-electric. Homes would be built with efficient, electric appliances like heat pumps, heat pump water heaters, and electric stoves instead of fossil fuel-powered equipment like gas and propane furnaces, hot water heaters, and stoves. Without appliances that combust fossil fuels, homes can reduce indoor air pollution and the corresponding negative impacts on human health, eliminate safety risks related to gas leaks and explosions, and reduce appliance energy use. Furthermore, an all-electric home would not contribute to particulates and ozone that result from combustion in buildings. A 2017 study found that outdoor air pollution from burning fuels in buildings lead to an estimated 841 early deaths in Michigan which corresponds to $9.4 billion in health impact costs for the state.[7] All-electric buildings also reduce greenhouse gas emissions over the lifetime of the building and can reach carbon neutral as the electric grid is increasingly run off renewable energy.
- **Amendment 2:** Improve air sealing requirement from the model 2021 IECC to 2ACH50 and install a heat recovery ventilation or energy recovery ventilation system (also called mechanical ventilation).[8] Increased air sealing reduces air leakage allowing homes to maintain comfortable indoor air temperatures and use their heating and cooling devices less. This reduces energy consumption and increases resilience to extreme weather, as the building can maintain comfortable temperatures for longer during a power interruption. Due to the added tightness of the building from this amendment, this analysis includes mechanical ventilation to comply with the state's mechanical code. Increased air sealing reduces air leakage allowing homes to maintain comfortable indoor air temperatures and use their heating and cooling devices less. They also allow for greater energy efficiency because energy or heat recovery mechanical ventilation can recover energy lost from ventilated air. Mechanical ventilation also circulates fresh outdoor air into the home more often and therefore improves indoor air quality and human health.
- **Amendment 3:** Amend the wall insulation prescription path from R20+5 to R20+7.[9] This would address the moisture issue that arises in Michigan's climate by thickening the exterior insulation. As moist air condenses on cold surfaces within the wall assembly, mold growth that leads to poor indoor air quality and material degradation begins to form. Increased wall insulation in compliance with Amendment 3 would correct this problem.

To assess the impact of the proposed amendments wholistically, this analysis studies three scenarios outlined below. Each scenario is analyzed in each of Michigan's climate zones (5, 6, and 7).

- **Scenario 1- Mixed-Fuel Baseline:** represents a mixed-fuel building built to the current Michigan code, 2015 IECC with the Michigan adopted amendments.[10] This is the baseline scenario for the analysis.

[7] https://iopscience.iop.org/article/10.1088/1748-9326/abe74c

[8] 2ACH50 is a measure of air sealing in a home and a primary indicator of energy efficiency. 2ACH50 denotes two air changes per hour at 50 Pascals (Pa). A building's ACH50 number indicates how tightly a building was originally constructed and gauges how much air the building leaks.

[9] R20+5 and R20+7 denote the wall insulation values. The R-value is a calculation which measures the flow of heat through an insulation product. The first value (R20) represents cavity insulation. The second value (R5 and R7) represents the continuous insulation.

[10] https://www.michigan.gov/lara/0,4601,7-154-89334_10575_17550-234789--,00.html

- **Scenario 2- 2021 IECC with Amendment 1:** represents a home built to the 2021 IECC code with an amendment that requires the homes to be all-electric.
- **Scenario 3- 2021 IECC with Amendment 1, 2, & 3:** represents a home built to the 2021 IECC code with amendments that requires the home to be all-electric and have increased air sealing and wall insulation with mechanical ventilation. These added amendments are detailed in the background section of this report.

Methods

To evaluate the cost effectiveness of the proposed code scenarios against the current Michigan code approved in 2015, this analysis calculates incremental construction and energy use costs using a standard reference home for Michigan's three climate zones (5, 6, and 7).[11] The standard reference home is the Pacific Northwest National Laboratory's (PNNL) prototype building for new residential construction. Scenarios 2 and 3 are modeled in accordance with the prescriptive compliance requirements of the 2021 IECC Residential Provisions alongside the proposed amendments. The analysis for this study is conducted following the Department of Energy's (DOE) methodology for evaluating cost-effectiveness of residential construction.[12]

To accurately account for local weather and utility rates, we selected a representative city for each climate zone. These cities were selected because they are some of the most populous in the region and are served by one of the major investor-owned utilities (IOU). Table 1 shows the representative cities for each climate zone alongside their respective gas and electric utilities.

Table 1: Representative cities, gas utilities and electric utilities for each Michigan climate zone.

Climate Zone	5	6	7
Cities	Detroit	Traverse City	Houghton
Electric Utility	DTE	Consumers	UPPCO
Gas Utility	DTE	DTE	SEMCO Gas

Using the Building Energy Optimization Tool (BEopt), we model the annual hourly energy use for the standard reference home in all three representative cities and then complete a lifecycle cost analysis (LCCA). BEopt is designed for residential buildings and is based on DOE's whole building energy simulation tool, EnergyPlus. For every residential building, heat transfer equations are implemented based on specific building characteristics such as shape, envelope, internal load, etc. To assess the impact of weather on building energy performance, we use typical meteorological year weather files (TMY3) for each of the representative cities.[13]

For utility costs, we used BEopt to model the utility costs based on energy consumption. Since BEopt analyzes home energy use at an hourly level, we were able to model the current utility rates as opposed to using a state average rate. Using the rates published in each utility's rate book, we were able to appropriately represent fixed and volumetric costs and account for rate differences across seasons and climate zones.

Once the monthly energy and cost impacts were calculated, we used BEopt to complete a 7-year LCCA. The LCCA calculates the total cost of ownership over a specified time period. To do this, BEopt converts

[11] https://www.energycodes.gov/prototype-building-models
[12] https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf
[13] https://nsrdb.nrel.gov/about/tmy.html

the cash flows into net present values.[14] Our analysis input assumptions are described in the following section and the results can be found in the results and discussion section.

Input Assumptions

In this section, we outline the assumptions for each scenario including the layout of the standard reference home, technology efficiencies, scenario costs, utility rates, and financial parameters. All other components not listed in the input assumptions section are the same across scenarios. Additionally, the heating and cooling set points are identical across scenarios. Each section details the reference source and an explanation of these assumptions.

1. **Standard Reference Home**: The standard reference home used in this analysis is representative of a single-family detached home in Michigan. As directed by the U.S. DOE, the protype is a single-family two-story home with a roughly 30-ft by 40-ft rectangular shape, 2,376 ft^2 of conditioned floor area excluding the basement. The window area is equal to 15% of the conditioned floor area equally distributed toward the four cardinal directions. The prototype has a heated basement foundation which is the most common foundation in Michigan with 36% of homes having this foundation type.[15] This design is based on the standard reference home used in PNNL's Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan study.
2. **Efficiencies**: For this analysis, the heat pump water heater, gas water heater, and air conditioner technologies have an efficiency that meets minimum code requirements and are sized to meet the needs for the prototype home.[16] We assumed the builder chose to comply with Section R408 (Additional Efficiency Package Options) by installing a gas furnace and air source heat pump with efficiencies listed in Table 2.[17] Note that although we use the minimum required efficiencies, cold weather heat pumps can perform better than the mandated minimum.[18] The Northeast Energy Efficiency Partnerships (NEEP) Cold Climate Air Source Heat Pump database currently contains thousands of tested and rated cold-climate commercial and residential air source heat pump products from dozens of manufacturers, available within the United States, many that have higher efficiency than the heat pump we analyzed.[19] These products are tested and rated to provide heating safely and efficiently down to 5 ºF and below, with minimal impacts to capacity or efficiency that used to occur with older heat pump models. Finally, we modeled an electric stove for the all-electric scenarios (2 and 3) and a gas stove for the mixed-fuel scenario (1). All-electric homeowners can increase stove efficiency and reduce utility costs if they purchase an induction stove which is not included in this analysis.

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[14] The cash flows are defined as the about of cash transfer out of the homeowners account including loan principal, loan interest, replacement costs, utility bills, loan tax deductions, rebates, federal tax credits, non-federal tax credits, and cash payments.
[15] https://www.energycodes.gov/sites/default/files/2021-07/MichiganResidentialCostEffectiveness_2021_0.pdf
[16] https://www.energy.gov/eere/femp/incorporate-minimum-efficiency-requirements-heating-and-cooling-products-federal
[17] https://codes.iccsafe.org/content/IECC2021P1/chapter-4-re-residential-energy-efficiency#IECC2021P1_RE_Ch04_SecR408
[18] https://www.energystar.gov/products/most_efficient/central_air_conditioners_and_air_source_heat_pumps
[19] https://ashp.neep.org/#!/

Table 2: The heat pump water heater, gas water heater, air conditioner, gas furnace, and air source heat pump efficiency values.

Appliance	**Efficiency**[20]
Air Source Heat Pump	SEER 16 and 10 HSPF
Gas Furnace	0.95 AFUE
Heat Pump Water Heater	EF =2.0 and FHR =50 gal/h
Gas Water Heater	EF =0.67 and FHR =67 gal/h
Central Air Conditioner	15.0 SEER and 12.5 EER
Electric Stove	EF=0.4
Gas Stove	EF=0.74

3. **Upfront Costs**: The scenario costs include amendment costs if applicable, the incremental cost of constructing a home to 2021 IECC compared to current Michigan code standards, and infrastructure costs. To estimate these costs, we use commercially available costs on websites like Home Depot and Grainger. We also use values from the RS Means database which estimates construction costs across the United States and is the preferred construction cost database of the National Home Builder's Association.[21, 22]
   a. **Amendment Costs:** The incremental appliance and building material costs for the proposed scenarios are calculated by summing the appliance costs, building materials costs, and the installation labor costs. Specifically, Amendment 1 includes the costs of electric appliances and installation labor costs. The cost of additional electric infrastructure is not included in this value and is provided in the next section. Amendment 2 includes the cost of mechanical ventilation, materials for increased air sealing to 2ACH50, and installation labor. Amendment 3 includes the cost of installation labor and additional continuous insulation for the external walls. All values are representative of the cost for an appliance or material needs that fit the prototype home size in Michigan. More details on how the appliance costs are calculated can be found in Appendix B.

[20] SEER = Seasonal Energy Efficiency Rating
HSPF= Heating Seasonal Performance Factor
AFUE= Annual Fuel Utilization Efficiency
EF= Energy Factor
FHR= First Hour Rating
EER= Energy Efficiency Rating
[21] https://www.rsmeans.com/?gclid=Cj0KCQiAubmPBhCyARIsAJWNpiOxAGeTQv1Uku41s-2-jFDt4P9h4DPMxToRuL2JYb1zCs71HNr8OuIaAspYEALw_wcB
[22] At a meeting of the cost effectiveness subgroup of the commercial committee for the 2024 IECC, a representative of the National Home Builder's Association requested that the cost effectiveness test for the 2024 IECC rely on incremental costs from the RS Means.

Table 3: Incremental costs of appliances and building materials for the proposed amendments in Michigan. Amendment 1 requires new homes to be all-electric. Amendment 2 improves air sealing requirement from the model 2021 IECC to 2ACH50. Amendment 3 amends the wall insulation prescription path from R20+5 to R20+7.

Amendments	**Incremental Appliance and Materials Costs [$/Building]**	**Source**
Amendment 1	$5,831	HVAC Direct, RS Means, Home Depot, Grainger
Amendment 2	$1,710	Supply House, Grainger, RS Means
Amendment 3	$400	Home Depot

b. **Infrastructure Costs:** Collectively called 'gas infrastructure', gas lines, regulators, meters, venting, and wiring components are needed to ensure a home has access to gas for use in its appliances. To safely provide electric power to an all-electric building, homes need increased electric infrastructure over the base code requirements. To do this, homes require a 100A to 200A service upgrade.[23] This analysis includes the costs of gas infrastructure for the mixed-fuel home in Scenario 1 and the incremental electric infrastructure costs for the all-electric home in Scenarios 2 and 3. These costs are summarized in Table 4. It is assumed that the electric and gas infrastructure costs are paid back within the study period. This assumption is made to appropriately characterize the lack of resale value of this infrastructure.[24] See Appendix B for more details about how these costs are calculated and their sources.

Table 4: Incremental upfront costs for installing the gas and electric infrastructure for a home in Michigan.

Infrastructure	Incremental Upfront Cost
Gas Infrastructure	$6,238
Electric Infrastructure	$628

c. **IECC 2015 vs IECC 2021 Construction Costs:** To evaluate the cost difference of the changes introduced by the 2021 IECC without amendments over the current Michigan code, PNNL estimated the incremental construction costs. These methods match the methods used in our analysis and are detailed more specifically in Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan.[25] These are incorporated in the analysis as upfront costs but paid for through the mortgage.

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[23] The base cost for 100A electric infrastructure is already included in the base price for the Michigan codes and is therefore not included in the electric infrastructure costs. The electric infrastructure costs only account for the additional cost to go from 100A to 200A electric service.

[24] For equipment that still has life remaining at the end of the analysis period, the resale value of that equipment is included in the last year of the analysis. The resale value (often call the residual value) is based on the percentage of life left in the equipment and the first cost of that piece of equipment. Since the 7-year scenarios have a short analysis period, we have removed the residual value from the costs. This allows us to compare the three scenarios without additional costs that skew the results.

[25] https://www.energycodes.gov/sites/default/files/2021-07/MichiganResidentialCostEffectiveness_2021_0.pdf

Table 5: The incremental construction costs between the 2021 IECC without amendments and the current Michigan 2015 IECC.

Climate Zone	5	6	7
2015 IECC vs. 2021 IECC (Heated Basement)	$4,787	$3,780	$5,264

4. **Utility Rates:** This study uses the most recent (as of November 2021) utility rate books to estimate gas and electricity rates for each climate zone's representative utility. Propane rates are not within the scope of this analysis; however, there are a significant amount of propane customers within Michigan. Propane rates are about two to three times higher than natural gas rates indicating that many Michigan residents would see even more cost benefits than this analysis reports. This analysis considers the monthly fixed service charges and volumetric charges for each gas and electric utility. We use utility rate books to estimate gas and electricity rates as opposed to other methods, like state averages, because rate books provide a more accurate representation of the cost dynamics. We selected the standard electric and gas rate structures available from each utility (see Table 6 and Table 7).[26] The standard rate structures do not necessarily present the highest financial savings for the all-electric scenarios. A more detailed evaluation of the existing utility rate structures is needed to determine the optimal rate for an all-electric home. It must be noted that these utility rates are representative of each climate zone and the city, but they are not constant across the climate zone because multiple utilities are operating in each climate zone. In addition to utility rates, interconnection rates are also retrieved.[27] This fee is representative of the one-time fee a gas utility charges to connect the home to the utility's gas infrastructure.

Table 6: The fixed, volumetric, and interconnection charges for the representative gas utilities in Michigan's three climate zones.

	Fixed Charge ($/Month)	**Volumetric Charge** ($/Mcf)	**Interconnection Costs**
SEMCO	12.25	8.6	$200 per meter
Consumers	12.6	8	$200 per meter
DTE	12.25	7.5	$200 per meter

[26] The rate structures used for the utilities in this analysis are as follows:
DTE: RESIDENTIAL SERVICE RATE - RATE SCHEDULE D-1.
Consumers: RESIDENTIAL SUMMER ON-PEAK BASIC RATE RSP.
UPPCO: Residential Heating Service

[27] DTE doesn't list connection fees in their rate book. Since both SEMCO and Consumers have an interconnection fee of $200 per meter, this analysis assumes DTE also has a $200 per meter interconnection fee.

Table 7: The fixed and volumetric charges for the representative electric utilities in Michigan's three climate zones.

Rate Structure	Fixed Charge [$/Mo.]	Volume Rate 1	Volume Charge [$/KW]	Volume Rate 2	Volume Charge [$/KW]	Volume Rate 3	Volume Charge [$/KW]
DTE	7.5	first 17kWh per day	0.0867	Over 17kWh per day	0.1066	N/A	N/A
Consumers	8	Off-Peak[28] between June and Sept	0.10064	On-peak between June and Sept	0.149965	Between Oct and May	0.100496
UPPCO	15	June-September	0.18803	First 500 kWh (October-May)	0.18803	For Excess (Oct.-May)	0.13423

5. **Financial and Economic Parameters:** The financial and economic parameters used in calculating the LCCA are based on the latest DOE cost-effectiveness methodology.[29] These values are retrieved from the PNNL Cost-Effectiveness of the 2021 IECC for Residential Buildings in Michigan study and used to inform this analysis' LCCA. Most notably, the analysis assumes a 10% down payment which includes appliance costs, gas and electric infrastructure costs, and construction costs. The mortgage is paid over a 30-year period; however, the analysis runs over a 7-year period.

Table 8: The financial and economic parameters used in calculating the LCCA for this analysis.

Down Payment	10% of home price
Mortgage interest rate	5%
Mortgage period	30 years
Marginal income tax rate, federal	15%
Marginal income tax rate, state	4.25%
Analysis period	7 years
Inflation rate	1.60%
Discount rate	5%

[28] *Consumers "On-peak" rate price is active from 2 to 7 p.m.,"Off-peak' rate price 7 p.m. - 2p.m.*
[29] https://www.energycodes.gov/sites/default/files/2021-07/residential_methodology_2015.pdf

Results and Discussion

This analysis reports that both all-electric 2021 IECC scenarios in Climate Zones 5 and 6 are cost-competitive over 7 years compared to the current code. Further analysis should explore the cost impact of Scenarios 2 and 3 in Climate Zone 7 if a high-performance cold climate heat pumps and heat pump friendly electric rate structures are used. Additionally, the cost impact for regions serviced by propane or delivered fuel should be further explored since this analysis only assumed natural gas use in the baseline scenario. Climate Zone 7 results are discussed in more detail in Appendix C. Alongside being cost-competitive, Scenarios 2 and 3 provide indoor and outdoor air quality improvements, increased comfort and energy efficiency, and reduced moisture problems. These results provide evidence that all-electric 2021 IECC codes with increase insulation, improved air sealing, and mechanical ventilation will benefit Michigan residents and should be fully considered in this code cycle.

1. Upfront Scenario Costs

The upfront costs for both all-electric scenarios (2 and 3) are more cost-effective than the mixed-fuel scenario (1) in all three climate zones. The upfront costs include the incremental appliance and material costs for each scenario, installation labor, infrastructure costs, and additional costs to comply with the 2021 IECC compared to the current Michigan code. The breakdown of each cost is outlined in the upfront costs section above.

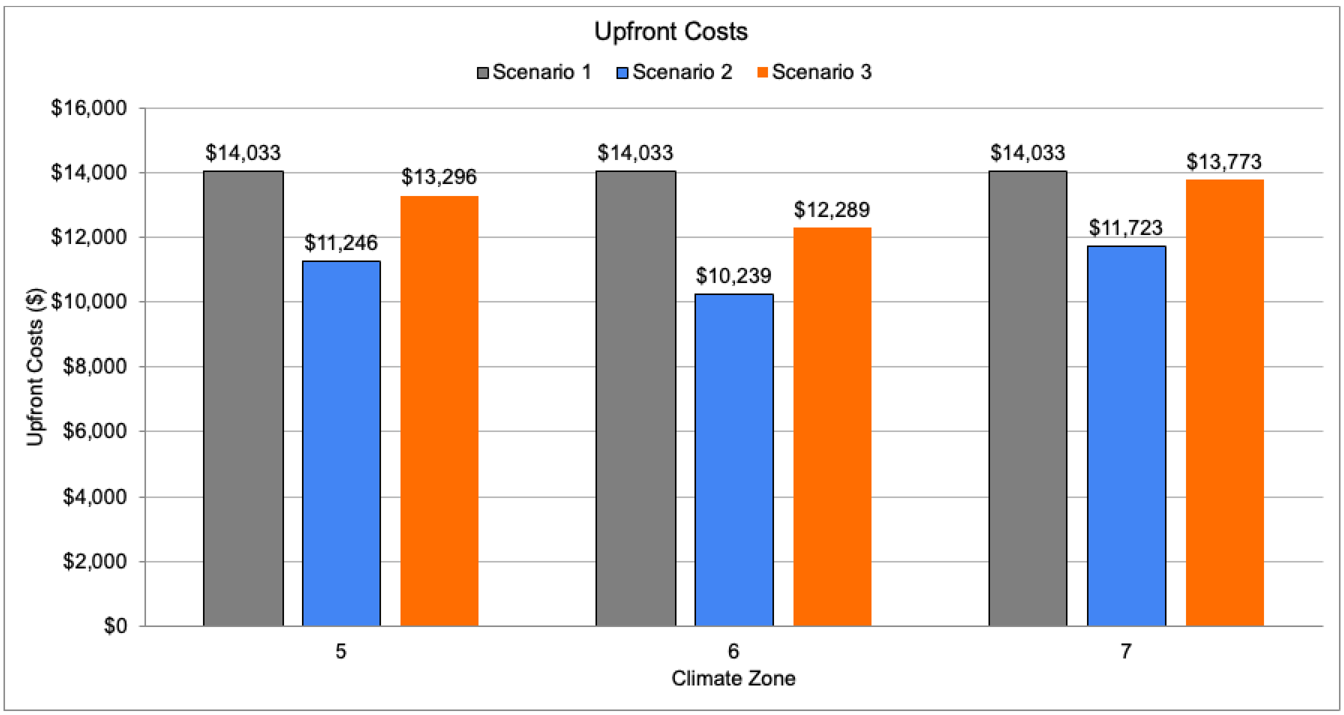

Figure 1: Upfront costs for each scenario. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with improved air sealing, increased wall insulation, and mechanical ventilation.

Across all climate zones, building an all-electric 2021 IECC code-compliant home (Scenario 2) reduces the upfront costs by 16-27%, delivering over $2,000 in upfront cost savings, compared to Scenario 1. Upfront costs for all-electric 2021 IECC code-compliant homes with increased air sealing, wall insulation, and mechanical ventilation (Scenario 3) are 2-12% less than the current code, delivering over $1,744 in upfront cost savings. In addition to cost benefits, Scenario 3 provides adequate ventilation and moisture prevention benefits.

All-electric homes benefit from cost savings associated with not needing to install the gas infrastructure. Eliminating the need for gas infrastructure costs saves a home more than $6,000 in upfront costs making up for the increased upfront cost of efficient electric equipment. Reducing upfront costs makes homeownership more accessible for Michigan residents. Potential homeowners will have a lower down payment and monthly mortgage payment for the all-electric home versus the mixed fuel home. This is especially advantageous for low or middle-income residents that may find it difficult to pay for a higher down payment or monthly mortgage. These upfront cost savings can be even higher for homeowners who are able to take advantage of rebates for efficient electric appliances provided by electric utilities. Although not included in this analysis UPPCO, DTE, and Consumers each have various rebates for efficient, electric appliances that would further reduce the upfront costs of an all-electric home.[30]

2. **Operational Costs and Energy Use**

Our analysis illustrates that the all-electric scenarios (2 and 3) reduce site energy use in all climate zones and have competitive operational costs compared to the mixed-fuel scenario (1) in Climate Zones 5 and 6. To comply with the law, we use the code mandated minimum efficiency for every appliance.[31]Although this analysis requires the use of code minimum efficiencies, there are many commercially available cold-weather heat pumps with higher performance than the heat pump we modeled. Despite not using highly efficient heat pumps, the all-electric scenarios have significant site energy savings compared to the current code. Figure 2, these homes reduce site energy use by 33 - 41%. These energy savings are the result of the added efficiency of Scenarios 2 and 3 and the use of heat pump technology. Because heat pumps move heat rather than produce it, modern cold weather air source heat pump products see efficiencies 2-3 times higher than electric resistance or gas combustion equipment.[32]

[30] UPPCO's, DTE's, and Consumer's available appliance rebates.
https://ee.uppco.com/Energy-Star
https://www.consumersenergy.com/residential/save-money-and-energy/rebates/heating-and-cooling
https://newlook.dteenergy.com/wps/wcm/connect/dte-web/home/service-request/residential/electric/electric-services/air-source-heat-pump

[31] Code mandate minimum means that the gas furnace and air source heat pumps are compliant with 2021 IECC minimums in section R408. All other appliances are compliant with the federally mandated minimum.

[32] https://ashp.neep.org/#!/

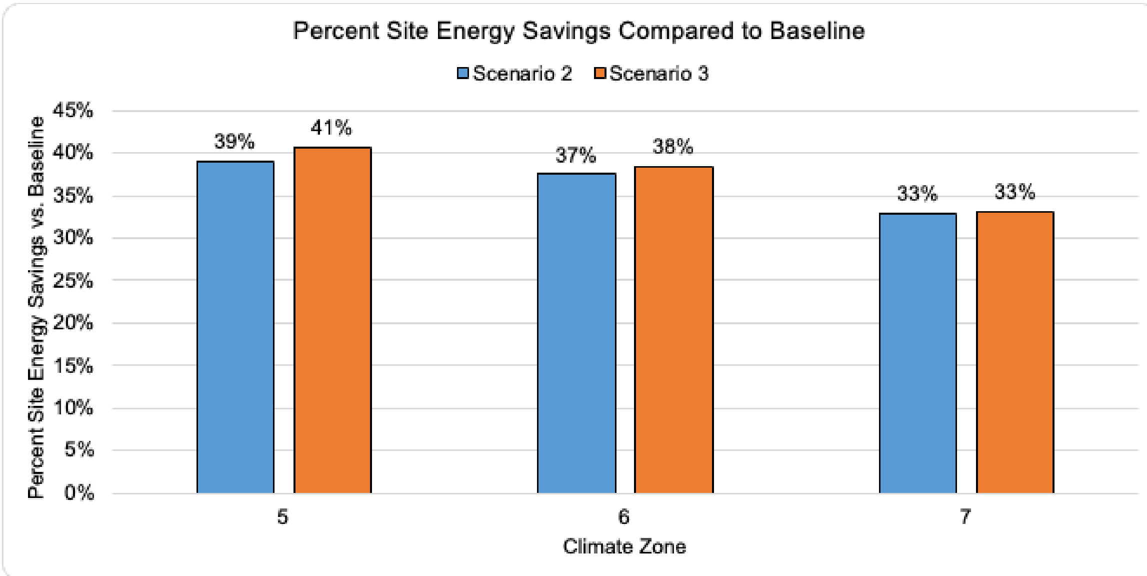

Figure 2: Site energy savings compared to baseline (Scenario 1) for all scenarios in all Climate Zones. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with improved air sealing, increase wall insulation, and mechanical ventilation.

These energy savings do not directly translate to utility cost savings. As shown in Figure 3, the difference in operational costs is comparable between the mixed-fuel building and the all-electric scenarios in Climate Zones 5 and 6.[33] The operational costs in this analysis include monthly utility bills, mortgage payments, and property taxes. In both climate zones, all scenarios are within $14 a month of each other. Given the source of uncertainty of future energy costs, these results indicate that the operational costs are cost-competitive with each other. The energy savings of the all-electric scenarios could be improved if homes install a more efficient heat pump, or they are enrolled in a utility rate better suited to the energy needs of an all-electric home.

[33] This analysis reports that climate zone 7 would be best suited for high performance cold climate heat pumps. Since the federal law doesn't allow states to specify appliance efficiency, we prioritize the analysis for Climate Zone 5 and 6 in this report and have included discussion of Climate Zone 7 in Appendix C. Although Climate Zone 7 is not cost competitive with the current code, given our conservative assumptions residents with all electric homes can still leverage the additional benefits such as increased indoor and outdoor air quality, reduced moisture problems, and increased energy efficiency and ventilation.

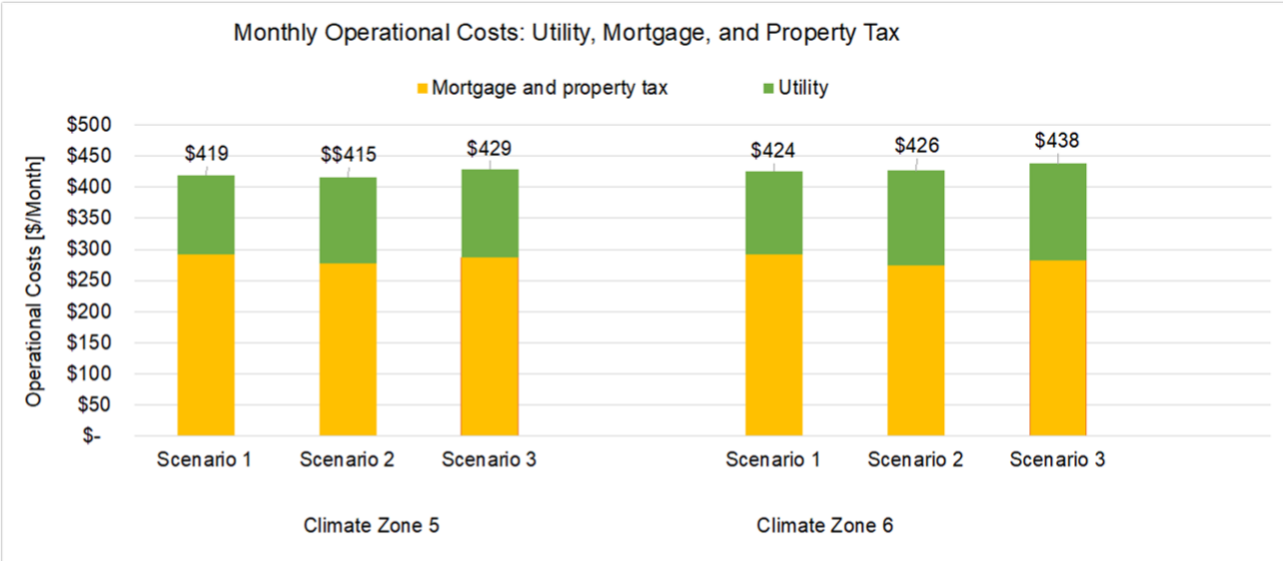

Figure 3: Operational Costs for all scenarios in Climate Zones 5 and 6. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with improved air sealing, increase wall insulation, and mechanical ventilation.

Although the operational costs are comparable across scenarios, when examining historic retail prices of gas and electricity in Figure 4, we can expect to see less volatility in the all-electric scenarios (Scenarios 2 and 3). This winter, for example, Midwest residential gas expenditures are expected to rise by about 46% whereas electricity prices are only expected to rise by about 3%.[34] Utility bill uncertainty is especially harmful to low-income customers who pay up to 30% of their income on housing costs and can't afford fluctuating utility bills.[35] Overall, this analysis illustrates that the operational costs of all-electric homes are cost competitive with mixed fuel homes. Leveraging efficient heat pumps and beneficial electric rate designs and considering volatile gas prices could make all-electric homes even more competitive. Further discussion of operational costs for Climate Zone 7 can be found in Appendix C.

[34] https://www.eia.gov/outlooks/steo/special/winter/2021_Winter_Fuels.pdf
[35] https://rmi.org/insight/decarbonizing-homes/

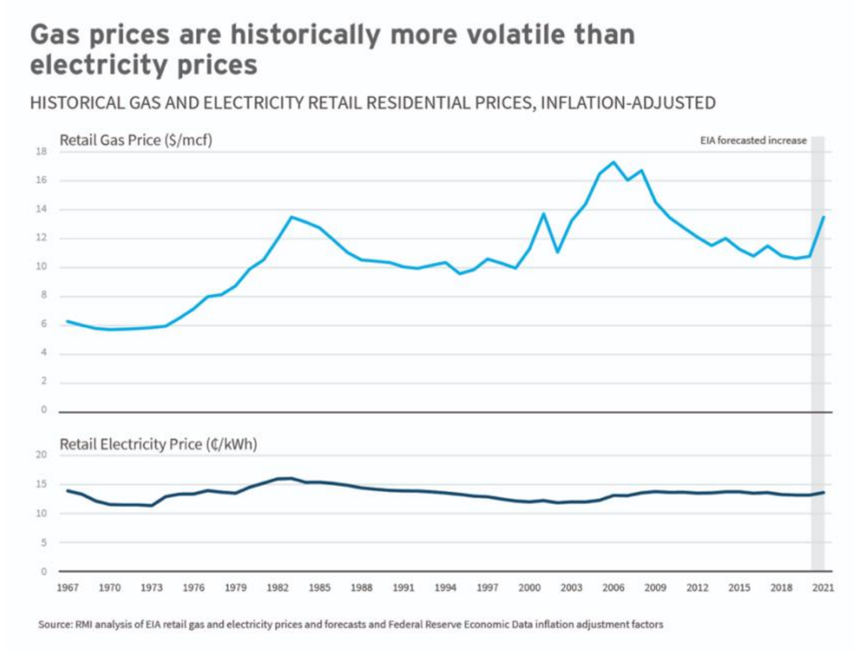

Figure 4: A comparison of U.S. electricity and gas prices since 1967.

3. **7-Year Lifecycle Cost Analysis**

This analysis finds that the lifecycle costs over 7-years for both the all-electric 2021 IECC scenarios (2 and 3) are cost-competitive compared to the mixed-fuel scenario (1) in Climate Zones 5 and 6. The lifecycle costs include the home down payment (10% of the upfront costs) and the monthly operational costs.

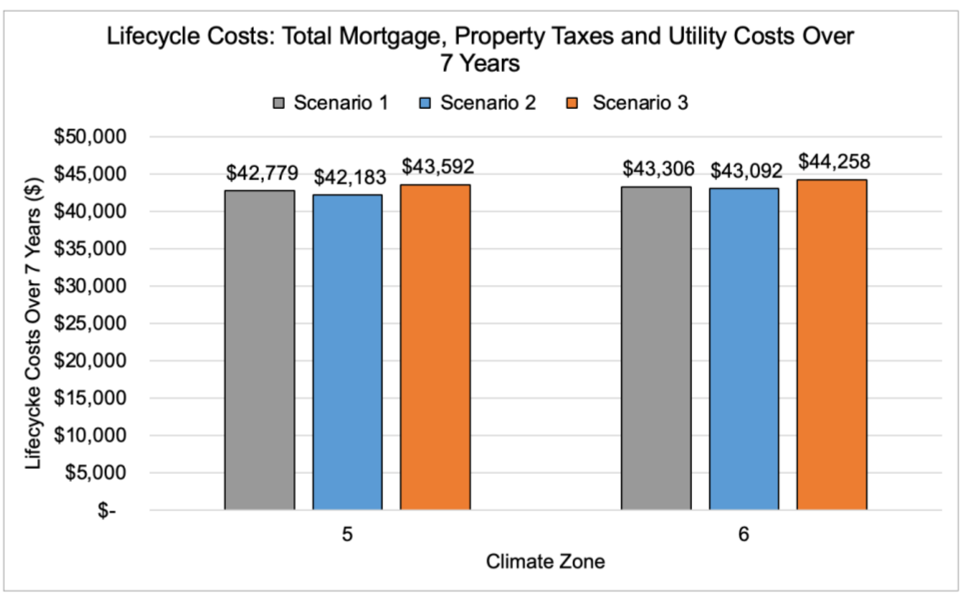

Figure 5: Lifecycle Costs for all scenarios in Climate Zones 5 and 6. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with increased air sealing and wall insulation.

These results illustrate that Scenario 2, the all-electric home, has the lowest lifecycle costs in Climate Zones 5 and 6. These cost savings range from $600 in Climate Zone 5 to $200 in Climate Zone 6 over the 7-year lifetime of this analysis. Scenario 3 has slightly higher lifecycle costs than the current code, but it is still effectively cost-neutral in Climate Zones 5 and 6 given the expected gas price volatility. These results illustrate that both all-electric scenarios are cost-competitive within 7 years for Climate Zones 5 and 6. Discussion of Climate Zone 7 results can be found in Appendix C. Given the comparable lifecycle costs and the lower upfront costs of the all-electric scenarios, the Michigan Construction Codes Commission should consider the additional benefits that come with the all-electric scenarios.

4. Societal Benefits

As a building's operation and environmental impact is largely determined by upfront decisions, building codes present a unique opportunity to ensure savings through efficient building design, technologies, and construction practices. Once a building is constructed, it is significantly more expensive to achieve higher efficiency levels through retrofits. Early investment in homes through building codes can ensure that Michigan experiences the long-term societal benefits of smart building practices.

a. **Indoor Air Quality:** On average, Americans spend 90% of their time indoors, meaning indoor air quality has a major impact on our health.[36] Amendments 1, 2, and 3 would reduce indoor air pollution within new homes.

- **Amendment 1** would eliminate on-site indoor air pollution caused by the combustion of fossil fuels inside the home by electrifying all appliances. The burning ('combustion') of fossil fuels like gas in buildings emits many harmful air pollutants, including nitrogen oxides (NO_x), carbon monoxide (CO), and fine particulate matter ($PM_{2.5}$). Eliminating on-site air pollution in new buildings would reduce early mortality and other health impacts like heart and lung disease. It is especially important to install electric stoves to protect health in new buildings. A comprehensive meta-analysis concluded that children living in homes with a gas stove are 42% more likely to experience asthma symptoms and 24% more likely to be diagnosed with asthma by a doctor compared to those living in homes with electric stoves.[37] These findings illustrate that electric appliances are necessary to ensure Michigan residents live in healthy new homes.
- **Amendment 2** requires homes to have higher air sealing than what IECC 2021 prescribes and installation of mechanical ventilation. These measures improve indoor air quality by regularly circulating outdoor air into the home. Without proper ventilation, a well-insulated and airtight home will seal harmful pollutants, like carbon monoxide, inside. It is difficult to provide adequate ventilation with unbalanced ventilation strategies such as exhaust fans and uncontrolled air leakage.[38] These unbalanced ventilation strategies often do not supply adequate oxygen supply and can leave excessive humidity and pollutants in the home. Requiring increased air sealing and complementary mechanical ventilation system in Amendment 2 will ensure Michigan residents will have clean, healthy ventilated air.

[36] https://www.epa.gov/report-environment/indoor-air-quality#:~:text=Americans%2C%20on%20average%2C%20spend%20approximately,higher%20than%20typical%20outdoor%20concentrations.
[37] https://academic.oup.com/ije/article/42/6/1724/737113?login=false
[38] https://rmi.org/airtightness-buildings-dont-let-slip-cracks/

- **Amendment 3** improves energy efficiency and reduces moisture and mold with increased wall insulation. By protecting the home from mold before it can grow, new homes with improved wall insulation can stop mold-related health impacts from ever occurring.

Adopting all-electric building codes with increased air sealing and mechanical ventilation will drastically improve indoor air quality and protect public health while also keeping energy costs low and the home comfortable.

b. Outdoor Air Quality: Direct emissions from buildings also impacts the outdoor air quality of local communities. Mixed-fuel buildings emit a range of pollutants that contribute to Michigan's nonattainment of National Ambient Air Quality Standards for ozone and $PM_{2.5}$. Appliances emit over 10% of all NOx (an ozone and $PM_{2.5}$ precursor) in the 10 Michigan counties that are either fully or partially in ozone or $PM_{2.5}$ nonattainment areas.[39] Ground-level ozone and particulate matter are also linked to short- and long-term health impacts such as asthma, pulmonary disease, or premature death and environmental impacts that negatively impact agriculture and vegetation.[40,41] Eliminating on-site emissions through appliance electrification and energy efficiency measures reduces health harming outdoor air pollution.

c. Greenhouse Gas Emissions: This analysis reports that building efficient, all-electric new homes in Michigan will reduce the state's climate impacts. Today, 20% of Michigan's greenhouse gas emissions are from on-site combustion equipment in residential and commercial buildings.[42] Efficient, all-electric buildings reduce emissions by eliminating on-site fossil fuel combustion in the home and leveraging the state's increasingly renewable electric grid. Electric power emissions in Michigan have fallen by over 30% in the last 15 years, and grid emissions are expected to continue to decrease given Governor Whitmer's executive order requiring the state to reach carbon-neutral by 2050.[43,44] Michigan's all-electric building stock can leverage the electric grid to ensure their buildings are running off increasingly cleaner electricity. To account for the uncertainty of the pace of renewable energy in Michigan, we used two future scenarios from the National Renewable Energy Laboratory (NREL)[45] to illustrate the possible range of emissions reductions:

- **Ambitious emission reduction:** Michigan's electric power sector reduces emissions 95% by 2035. This emission scenario would meet Governor Whitmer's climate goals early.
- **Conservative emission reduction:** Michigan's electric power sector reduces emissions 95% by 2050. This emission scenario assumes coal is online until 2044 and would not meet Governor Whitmer's climate goals.

This analysis illustrates that the all-electric scenarios (2 and 3) are emissions savings compared to the gas alternative (Scenario 1) in both an ambitious and conservative emission reduction future.

[39] RMI analysis of EPA 2017 National Emissions Inventory data, https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data#dataq.
[40] https://iopscience.iop.org/article/10.1088/1748-9326/abe74c
[41] https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics#:~:text=What%20are%20the%20environmental%20effects,vegetation%20during%20the%20growing%20season.
[42] https://www.eia.gov/environment/emissions/state/
[43] https://www.eia.gov/environment/emissions/state/
[44] https://www.michigan.gov/whitmer/0,9309,7-387-90499_90640-540289--,00.html
[45] https://www.nrel.gov/analysis/standard-scenarios.html

The more quickly emissions fall from the electricity sector, the larger the emissions savings from the all-electric scenarios. Under the ambitious renewable adoption case, the all-electric scenarios reduce emissions by 10% to 20% within the 15-year lifetime of the appliance compared to the current code. These emissions savings will continue to grow throughout the lifetime of the home. By 2050, when Governor Whitmer has ordered the state's economy to be carbon-neutral, emissions savings for an all-electric home built in 2022 can grow to 33%. Figure 6 shows the cumulative emissions until 2050 of a home built in 2022 for each scenario. All-electric homes can achieve a near complete reduction in the building's operational emissions if they provide their home's electricity needs fully with renewable energy. This rate of reduction is not possible with homes that combust fossil fuels to meet part of the home's energy needs.

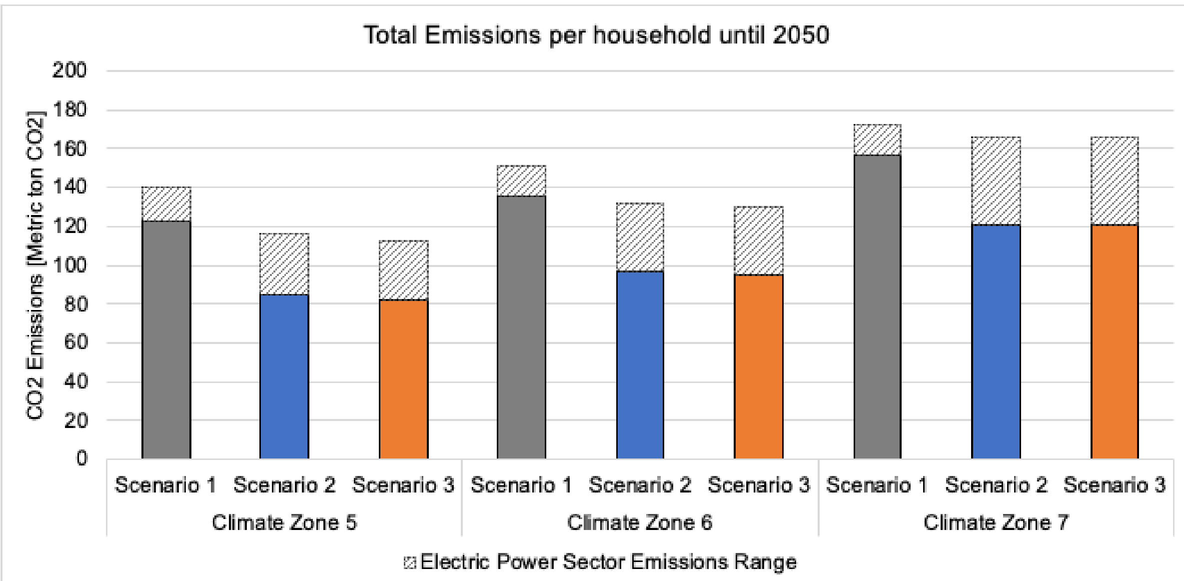

Figure 6: CO_2 emissions per household until 2050 assuming ambitious and conservative electric power emissions. The gray, hatched bars represent the possible emissions range depending on the rate of electric power decarbonization. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with increased air sealing and wall insulation.

d. **Reduced Moisture Problems:** In the residential chapter of the 2021 IECC, the wall insulation requirement for Climate Zones 5 and 6 includes the option to use R20 +5 ci. This insulation requires R-20 for cavity insulation along with R-5 for exterior continuous insulation. Unfortunately, this type of insulation assembly may pose moisture problems in Michigan's climate zones. Condensation within the wall assembly is a significant issue in cold climates. As warm, moisture-laden air moves through a wall assembly, it condenses on cold surfaces like exterior sheathing. This liquid moisture facilitates pathogen growth that leads to poor indoor air quality and material degradation. As vapor barriers in wall assemblies are rarely perfect, one recommended strategy (such as by the US Office of Efficiency and Renewable Energy) is to add continuous insulation on the outside of the building sheathing to eliminate condensation. Research shows that the exterior insulation R-value should be, at a minimum, roughly 35% of the cavity insulation.[46] In the case of R20 + 5, the exterior insulation is 25% meaning there is insufficient exterior insulation to protect against cold-weather condensation in the walls. To avoid this problem, Amendment 3 proposes to change the prescriptive R20 + 5ci requirement to R20 + 7ci. The additional exterior insulation would protect against cold-weather condensation and potential moisture-related problems.

e. **Resilience:** An efficient building-shell is a key mechanism for improving the comfort in a building by providing greater control for the occupant and reducing unwanted temperature variations. Building envelope improvements are also a key mechanism to protect building occupants against the extreme weather events we are already experiencing due to climate change. Effective insulation and air sealing can provide essential "hours of safety" during severe weather events and power outages, resulting in critical extra days before the onset of life-threatening conditions from extreme temperatures.[47] [48] This benefit of greater efficiency is called "passive survivability" and provides an important health and safety rationale for stronger energy codes. Upgrading Michigan's building codes to 2021 IECC with Amendments 2 and 3 will increase the resiliency of new Michigan homes and improve the safety for residents.

[46] https://www.buildingscience.com/documents/digests/bsd-controlling-cold-weather-condensation-using-insulation

[47] https://rmi.org/insight/hours-of-safety-in-cold-weather/

[48] https://www.urbangreencouncil.org/babyitscoldinside

Conclusion

This analysis studies the cost and energy use impacts of three scenarios in Michigan's three climate zones for a 7-year analysis period.

1. **Scenario 1- Mixed-Fuel Baseline:** represents a mixed-fuel building built to the current Michigan code, 2015 IECC with the Michigan adopted amendments.[7] This is the baseline scenario for the analysis.
2. **Scenario 2- 2021 IECC with Amendment 1:** represents a home built to the 2021 IECC code with an amendment that requires the homes to be all-electric.
3. **Scenario 3- 2021 IECC with Amendment 1, 2, & 3:** represents a home built to the 2021 IECC code with amendments that requires the home to be all-electric and have increased air sealing and wall insulation with mechanical ventilation.

The 7-year cost analysis was completed in service of the Stille-Derossett-Hale Single State Construction Code law which requires the Construction Codes Commission to consider the costs and benefits of any new code proposal over a 7-year period.[49] In addition to the scenarios analyzed in this report, members of the Michigan Building Decarbonization Coalition submitted additional amendments to the residential code (see Table 9). These amendments would allow Michigan residents to install climate aligned technology when they are able while ensuring the future retrofit is not cost prohibitive. More discussion of the readiness amendments is available in Appendix A.

Table 9: A list of additional readiness amendments with a description and states that are considering these amendments.

Additional Amendments	Description	Cost Savings to Install During Instead of After Construction	Jurisdictions Considering Amendments
All-Electric Readiness	Install electric infrastructure needed to install all-electric appliances	Up to $6,000	Wisconsin, Washington State, Denver, CO, Washington, DC, New York State, Massachusetts, Connecticut and California
EV-Readiness	Install electric infrastructure needed to install an EV charger	$1,000-$2,500	Ann Arbor, Michigan, Denver, Colorado, Washington, DC and Wisconsin
Solar PV-Readiness	Install electric infrastructure needed to install solar PV.	$4,000	Washington, DC, and it has been adopted in Vermont and Massachusetts.
Demand Response Water Heaters	Require demand response water heaters.	$180/year	California, Oregon, and Washington have passed it. Wisconsin is considering
Battery Storage-Readiness	Install electric infrastructure needed to install battery storage	More Research Required	More Research Required

[49] http://www.legislature.mi.gov/documents/mcl/pdf/mcl-act-230-of-1972.pdf

The results of this analysis indicate that the Michigan Construction Codes Commission should adopt the following residential building codes:

- **All-electric 2021 IECC with improved air sealing, increased wall insulation, and mechanical ventilation in Climate Zones 5 and 6.**
- **Electric-Ready 2021 IECC with improved air sealing, increased wall insulation, and mechanical ventilation in Climate Zone 7.**

All-electric 2021 IECC with improved air sealing, increased wall insulation, and mechanical ventilation (Scenario 3) has minimal impact on the monthly and overall costs of new buildings in Climate zones 5 and 6 while delivering important benefits to residents like improved indoor air quality, reduced negative health outcomes, more resilient and safe homes, and reduced moisture problems Since all-electric codes are not explicitly cost-effective in Climate Zone 7, the Construction Code Commission should adopts electric-ready codes in this region. This will keep costs down while future proofing these homes and enabling an affordable transition to electric appliances in the future. Additional consideration should be given to customers that would normally be served by propane in Climate Zone 7. Although outside the scope of this analysis, propane prices are two to three times more expensive than the natural gas prices used in Scenario 1 suggesting that current propane customers could see even greater utility bill savings than reported in this analysis.

In conclusion, the Michigan Construction Codes Commission should adopt all-electric 2021 IECC with improved air sealing, increased wall insulation, and mechanical ventilation in Climate Zones 5 and 6 to ensure Michigan begins building healthy, climate-aligned homes in 2023. The proposed code amendments will improve indoor and outdoor air quality which will have positive health impacts for residents of Michigan. The proposed amendments will also ensure the home is highly energy efficient and reduce problematic moisture issues that are especially prevalent in the cold climate of Michigan and expensive to repair. Finally, the proposed code scenarios remain cost-neutral against the current code while reducing emissions and ensuring the state aligns with Governor Whitmer's climate objectives. The Construction Codes Commission has a clear pathway to make Michigan a leader in climate change and healthy buildings while ensuring that owning a home in Michigan remains affordable for all.

Appendix A: Other Amendments

In order to meet Governor Whitmer's 2050 carbon neutrality goal, Michigan must transition away from combustion equipment in buildings and install electric appliances powered by renewable electricity. New buildings also need to be EV-ready to meet Michigan's growing demand for electric vehicles. Finally, the state's building must be grid interactive and battery storage-ready to balance electricity demand. The following amendments will allow Michigan to implement smart construction practices that support climate-aligned technology without being cost-prohibitive.

1. **Electric Readiness:** As we have detailed throughout this report, all-electric new construction is cost-competitive when compared to building a mixed-fuel home in Climate Zones 5 and 6. Climate Zone 7 is not found to be cost-competitive with the equipment and rates modeled. Electric readiness can serve as a bridge for Climate Zone 7 residents to switch to all-electric appliances when the costs are competitive. Electric readiness requires new homes to install the infrastructure needed to accommodate all-electric appliances so that it is easy and affordable to switch. Electric Readiness should be adopted in Climate Zone 7 because it allows residents to have the option to affordably retrofit their home when they are ready without leaving residents with cost-prohibitive retrofits later. **Research completed by NBI and partners using RSMeans finds that retrofitting a home later can cost up to $6,000 whereas installing electric ready infrastructure at the time of construction costs about $600.** To reduce expensive retrofit costs, it is therefore critical that Michigan's building codes require electric-ready infrastructure. Similar amendments are being explored in Wisconsin, Washington State, Denver, CO, Ann Arbor, MI, Washington, DC, New York State, Massachusetts, Connecticut and California.
2. **Electric Vehicle Readiness:** The widescale adoption of electric vehicles (EVs) is a key climate strategy to reduce GHG emissions from Michigan's transportation sector. Fortunately, the transition to electric vehicles (EVs) is already underway and auto manufacturers in Michigan are embracing this change, especially General Motors who recently announced it would only manufacture electric vehicles by 2035.[50] The number of EVs on U.S. roads is projected to grow from one million vehicles at the end of 2018, to 18.7 million by 2030.[51] To charge these new EVs, the U.S. will need 9.6 million charge ports, a substantial portion of which will be installed in single and multi-family residential buildings.[52] A major barrier to the transition to EVs is the lack of charging infrastructure at homes and businesses and the potential need for extensive electrical upgrades. It is more cost-effective to ensure a building is "EV ready" when it is being built or undergoing major renovations than trying to add equipment after the building is constructed. To reduce expensive retrofit costs, it is therefore critical that Michigan's building codes require parking spaces to be EV-ready. The City of Ann Arbor approved an EV-readiness ordinance in January 2021 and similar proposed code changes are being considered in Denver, Colorado, Washington, DC and Wisconsin.

   By adding provisions in the energy code to aid the transition from gas-powered to electric-powered vehicles, Michigan will not only reduce carbon emissions in the state substantially but will also reduce other pollutants. Vehicle emissions are the largest source of carbon monoxide, nitrogen oxides, and other smog-causing air pollution in cities. Research currently undertaken by NBI and

[50] https://www.nytimes.com/2021/01/28/business/gm-zero-emission-vehicles.html

[51] https://www.eei.org/resourcesandmedia/newsroom/Pages/Press%20Releases/EEI%20Celebrates%201%20Million%20Electric%20Vehicles%20on%20U-S-%20Roads.aspx

[52] https://www.eei.org/resourcesandmedia/newsroom/Pages/Press%20Releases/EEI%20Celebrates%201%20Million%20Electric%20Vehicles%20on%20U-S-%20Roads.aspx

partners indicate that the cost of the added infrastructure to make a home EV-ready is estimated to be $500 at the time of construction. If a home was not made EV-ready but chose to add an EV charger later with an insufficient supply infrastructure in place, the cost of the retrofit (if the retrofit is feasible) was found to be between $1,500 to $3,000. **Therefore, adding the infrastructure to make a home EV-ready saves $1,000 to $2,500 for the average homeowner who must add an EV charger later.**

3. **Solar PV Readiness:** It is more cost-effective to ensure a building is "solar ready" when it is being built or undergoing major renovations than trying to add equipment after the building is constructed. If a building is not built to be "solar ready," it can be technically infeasible or economically prohibitive to install solar later. Therefore, it is crucial to remove this barrier in new residential buildings so that homeowners can install renewable energy on-site to enable a low-cost carbon free grid. This amendment would require all new homes in Michigan to be solar ready by requiring a designated 300 square foot minimum "solar ready zone" on the roof. Conduit and wire from this zone must be installed and space in the electrical panel must be reserved for a future solar array. Homes where solar is not feasible due to shading or not enough solar exposure due to orientation are exempt. Recent analysis by NBI and partners using cost data from RS Means indicates that adding the infrastructure to make a home solar ready would cost $435 or $0.17 per square foot for a typical home at the time of construction. According to an NREL report, if a home is not made solar ready but chooses to add solar later, the cost of the retrofit (if the retrofit is feasible) is $4,373 or $1.75 per square foot. **Therefore, adding the infrastructure to make a home solar ready saves about $3,938 or $1.58 per square foot for homeowners who choose to add solar later.** The proposed change is in Appendix RB Solar-Ready provisions of the 2021 IECC and is being considered in Washington, DC, and previous versions have been adopted in Vermont and Massachusetts.
4. **Battery Storage Readiness:** Energy storage will soon become critical to aid in this transition by storing energy to match grid demands. Energy storage is expected to grow by over 40% each year until 2025[53], and Michigan, because of its manufacturing background and experience in batter-storage technology for cars, is becoming a clear leader in this market. These systems could also improve Michigan's economy, present a cost savings opportunity for Michigan homeowners in the future, and increase Michigan's resilience to power outages. Incremental costs of ensuring buildings are energy storage ready will increase costs but those costs are minor compared to retrofit costs for buildings who choose to add storage later when a building is not storage ready. These incremental cost impacts include additional design professional fees, markings on the panels, and additional construction costs only if there were not spare square footage available in the equipment or storage rooms where panels are generally located. In that case, it would be equal to the construction costs for an additional 8 square feet of storage space.
5. **Demand Response Water Heaters**: As Michigan increases the amount of electricity generated from renewables to meet the state's carbon neutrality goals, buildings must be prepared to aid in this transition by reducing energy use to match grid demands. Demand response controls for water heating and space conditioning are an inexpensive and proven technology that adds this needed functionality to buildings. In addition, demand responsive functionality will present a cost-saving opportunity for buildings in the future. Demand response requirements for electric storage water

[53] https://www.irena.org/newsroom/articles/2020/Mar/Battery-storage-paves-way-for-a-renewable-powered-future#:~:text=Globally%2C%20energy%20storage%20deployment%20in,40%25%20each%20year%20until%202025.&text=Currently%2C%20utility%2Dscale%20stationary%20batteries,%2C%20complementing%20utility%2Dscale%20applications.

heaters based on ANSI/CTA-2045-B will standardize the socket, and communications protocol, for heat pump water heaters so they can communicate with the grid and demand response signal providers. Demand responsive thermostats were found to be extremely cost effective in 2011. Every dollar spent on a demand response thermostat yielded between $2 to $3 in monthly operating cost savings over a 15-year period.[54] In the 10 years since, equipment prices have decreased (less than $60 for a basic DR thermostat compared to just under $30 for a basic 7-day programmable thermostat). Demand response controls for water heaters, which costs about $170, become cost effective when enrolled in a demand response program. Armada Power customers in Ohio who enrolled their water heaters in a demand response program saved $184 annually by enrolling in the program. **If Michigan utilities institute a similar program to shape demand, a customer would reap $12 in energy cost savings for every $1 spent on the additional controls.** Versions of this standard are included in codes or other requirements in California, Oregon, and Washington, and under consideration in several other states including Wisconsin.

6. **Battery Storage Readiness:** As Michigan increases the amount of electricity generated from renewables, buildings must be prepared to aid in this transition by storing energy to match grid demands. Energy storage is expected to grow by over 40% each year until 2025[55], and Michigan, because of its manufacturing background and experience in batter-storage technology for cars, is becoming a clear leader in this market. These systems could also improve Michigan's economy, present a cost savings opportunity for Michigan homeowners in the future, and increase Michigan's resilience to power outages. Incremental costs of ensuring buildings are energy storage ready will increase costs but those costs are minor compared to retrofit costs for buildings who choose to add storage later when a building is not storage ready. These incremental cost impacts include additional design professional fees, markings on the panels, and additional construction costs only if there were not spare square footage available in the equipment or storage rooms where panels are generally located. In that case, it would be equal to the construction costs for an additional 8 square feet of storage space.

Appendix B: Scenario Costs

1. **Appliance Costs:** The total appliance costs for the proposed building code scenarios are calculated by summing the appliance costs and the installation labor costs. The cost of the appliance, estimate

[54] https://info.aee.net/peak-demand-reduction-report

[55] https://www.irena.org/newsroom/articles/2020/Mar/Battery-storage-paves-way-for-a-renewable-powered-future#:~:text=Globally%2C%20energy%20storage%20deployment%20in,40%25%20each%20year%20until%202025.&text=Currently%2C%20utility%2Dscale%20stationary%20batteries,%2C%20complementing%20utility%2Dscale%20applications.

labor costs, and total costs are listed Table 10 alongside the source of our cost estimates. Space conditioning equipment is sized based on the prototype and local weather files. All other appliances are standard size regardless of climate zone. Labor costs are estimated at $115/hour as an assumed average cost for Michigan's HVAC services.[56]

Table 10: Upfront costs for appliance costs in Michigan.

Appliance	Appliance Cost	Labor Hours	Labor Cost	Total Cost	Source
Air Source Heat Pump	$2,331	4	$460	$2,791	RS Means[57]
Gas Furnace	$1,119	5	$575	$1,694	HVAC Direct, RS Means
Gas Water Heater	$957	4	$460	$1,417	Home Depot, RS Means
Heat Pump Water Heater	$1,013	7	$747	$1,760	Home Depot, RS Means
Electric Stove	$935	3	$345	$1,280	Home Depot, RS Means
Gas Stove	$829	3	$345	$1,174	Home Depot, RS Means
AC	$2,078	7	$805	$2,883	Grainger, RS Means

2. **Air Sealing and Wall Insulation Costs:** Amendments 2 and 3, included in Scenario 3, require higher air sealing, mechanical ventilation, and more wall insulation to reduce moisture issues and improve household efficiency. Amendment 2 requires mechanical ventilation to ensure there are enough air changes within the home to maintain high air quality due to the lower air leakage. The mechanical ventilation system and additional air sealing materials costs about $1,250. Coupled with four hours of installation labor leads to a total cost of $1,710 for the entire amendment. Amendment 3 costs $400 for labor and building materials. The difference between 1" of exterior insulation (R-5) and 1.5" (R-7.5) is about $7 per board (which is equivalent to 32 square feet). For a typical home, with roughly 1,800 square feet of wall area, the additional cost is about $400 per home. The costs to repair moisture problems in walls far outweigh the $400 needed to prevent moisture issues.

3. **Infrastructure Costs:**
    a. Scenario 1: The mixed fuel scenario in our analysis includes the upfront gas infrastructure cost. Gas infrastructure includes the gas line, regulator, gas meter, gas venting, and wiring components needed to ensure a home has access to gas. These do not include gas line extension costs which utilities charge new customers to extend gas lines to meet a new home. This value is excluded because we were not able to get an accurate estimate. Without

[56] https://www.rsmeans.com/?gclid=Cj0KCQiAubmPBhCyARIsAJWNpiOxAGeTQv1Uku41s-2-jFDt4P9h4DPMxToRuL2JYb1zCs71HNr8OuIaAspYEALw_wcB
[57] https://www.rsmeans.com/
RS Means is a database that estimates the costs of construction codes.

this value, the costs associated with Scenario 1 underestimates the real upfront costs that should be applied under the current Michigan code.

b. All-Electric Scenarios 2 and 3: The all-electric scenarios include additional electrical infrastructure costs that are not included in the mixed fuel scenario. This electric infrastructure includes additional wiring and equipment costs to ensure an all-electric home can safely provide electric power to all appliances. The additional cost in this study includes the incremental cost of upgrading a home to have 200A electric service instead of 100A electric service.

The sources for both gas and electric infrastructure alongside a breakdown of the costs are presented in Table 11.

Table 11: Upfront costs for infrastructure in Michigan.

	Infrastructure Component	**Component Cost**	**Labor Hours**	**Labor Cost**	**Total Cost**	**Source**
Gas Infrastructure	Gas Line	$2,440.94	8	$920.00	$3,360.94	Grainger[58], RS Means
	Gas Regulator	$53.06	0.5	$57.50	$110.56	Grainger, RS Means
	Gas Meter	$1,952.76	2.5	$287.50	$2,240.26	Grainger, RS Means
	Gas Venting	$212.26	1.25	$143.75	$356.01	Grainger, RS Means
	Wiring	$64.56	1	$115.00	$179.56	Grainger, RS Means
Electric Infrastructure	Incremental cost of 100A to 200A Service Upgrade	$628	0	0	$628.00	Grainger

[58]RS Means database estimates construction costs across the United States. Grainger is an industrial supplies company that sells equipment products across the US.

Appendix C: Climate Zone 7 Results

To comply with code minimums, this analysis used the minimum efficiency code compliant appliances. As discussed throughout this report, heat pumps are valuable for their high efficiency ratings and energy savings. Since we did not use the most efficient appliances commercially available, the all-electric scenarios did not realize their maximum energy or cost savings potential. Due to northern Michigan's high electricity prices and very cold climate, Climate Zone 7 is best suited for high performance cold climate heat pumps and all-electric friendly rate structures. However, the narrow analysis required by the Stille-Derossett-Hale Single State Construction Code Act does not show that Scenarios 2 and 3 are cost-effective in Climate Zone 7. Although we choose to prioritize Climate Zones 5 and 6 throughout this report, we have outlined the results for Climate Zone 7 in this appendix. To fully understand the economics of electrification in Climate Zone 7, a further analysis on higher performing heat pumps, optimized rate studies, and the impacts on non-gas customers should be conducted. Fuel type is an especially important sensitivity to consider since Climate Zone 7 coincides with areas where there is a lot of electric resistance and propane usage.[59] For this customer class, studies show that cold weather heat pumps produce significant cost savings to customers.[60] Due to resource constraints, this analysis did not fully explore the cost savings associated with an efficient heat pump for customers who would have otherwise heated their home with electric resistance or propane.

1. **Upfront Costs:** The upfront cost for Climate Zone 7 was previously outlined in the results section. As shown in Figure 7, **the all-electric scenarios (2 and 3) have lower upfront costs than the current Michigan code.** An all-electric 2021 IECC code with insulation and air sealing amendments reduces costs by over $200. The all-electric 2021 IECC code reduces costs by over $2,000.

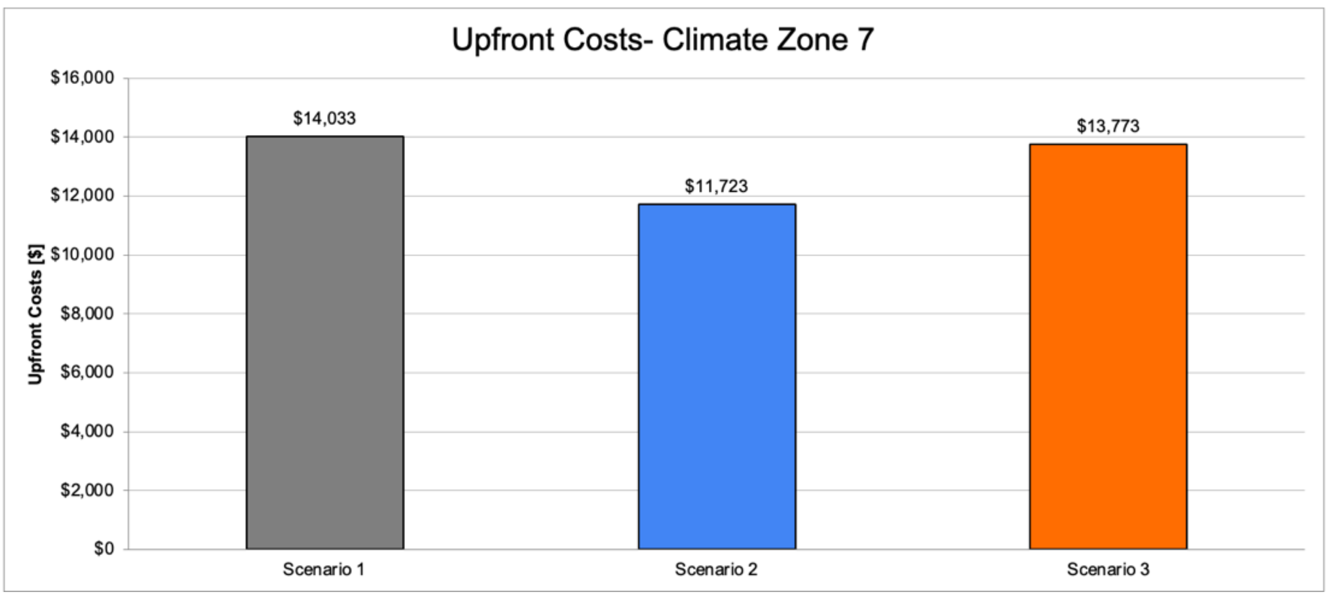

Figure 7: Upfront costs for each scenario in Climate Zone 7. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with increased air sealing and wall insulation.

[59] https://www.michigan.gov/mpsc/consumer/petroleum
[60] https://map.rewiringamerica.org/states/michigan-mi

The upfront costs for the mixed fuel home are more than the all-electric homes in Climate Zone 7 because of gas infrastructure costs. To install the equipment needed to deliver natural gas to the home, homeowners pay over $6,000 upfront. Additionally, many upper Michigan utilities (like UPPCO and WE Energies) have rebates for efficient electric appliances that would reduce these upfront costs even more.

2. **Operational Costs:** The operational costs in this analysis include monthly utility bills, mortgage payments, and property taxes. As shown in Figure 8, **the all-electric scenarios (2 and 3) have higher operational costs than the current Michigan code in Climate Zone 7 , but this can be improved with higher efficiency heat pumps and optimized electric rate structures.** An all-electric 2021 IECC code with insulation and air sealing amendments increases monthly costs by $83. The all-electric 2021 IECC code increased operational costs by over $74 per month.

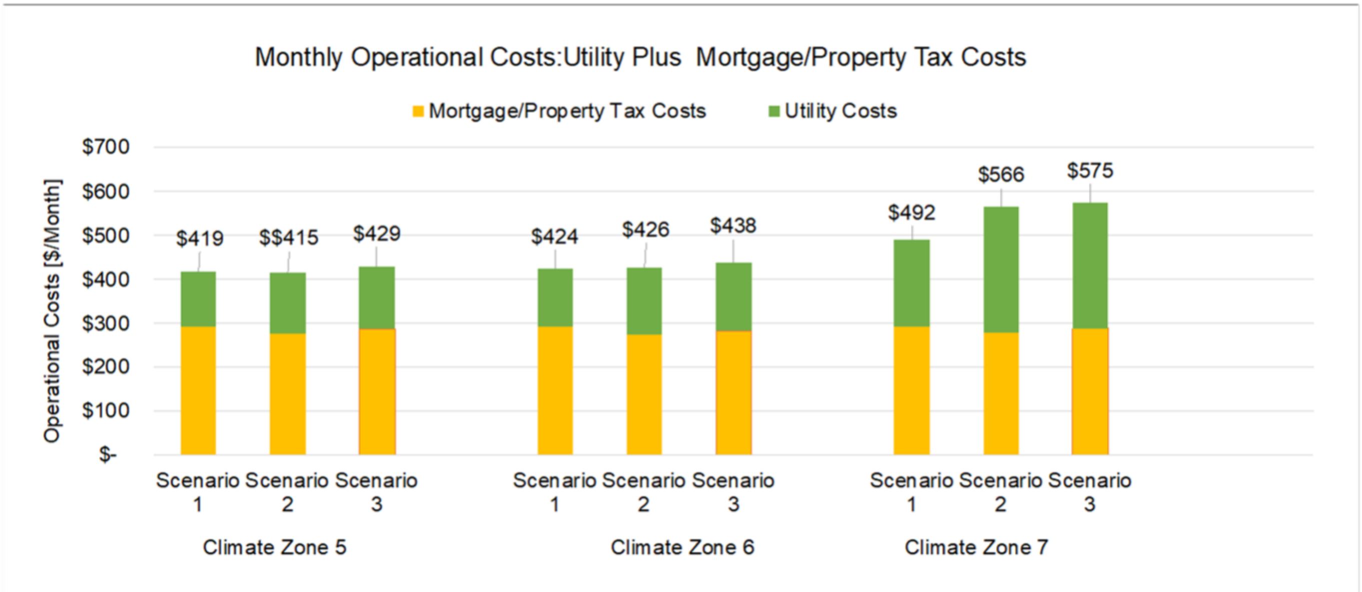

Figure 8: Operational Costs for all scenarios in Climate Zones 5, 6, and 7. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with increased air sealing and wall insulation.

The operational costs for the mixed-fuel gas home are less than the all-electric homes in Climate Zone 7 mainly because northern Michigan has especially high electricity costs compared to natural gas prices. However, Climate Zone 7 has a high number of residents on propane or electric resistance heating. Propane fuel is about two to three times more expensive than natural gas, making electric appliances an even more attractive option compared to combustion appliances.[61] Studies show that on average, propane customers would save $564/year in utility bills and electric resistance customers could save $748/year if instead they used a high-efficiency all-electric heat pumps.[62]

[61] https://www.eia.gov/outlooks/steo/special/winter/2021_Winter_Fuels.pdf
[62] https://map.rewiringamerica.org/states/michigan-mi

3. **Lifecycle Costs over 7 years:** The lifecycle costs include the home down payment (10% of the upfront costs) and the monthly operational costs. **The all-electric scenarios (2 and 3) have higher lifecycle costs than the current Michigan code in Climate Zone 7.** An all-electric 2021 IECC with insulation and air sealing amendments increases 7-year lifecycle costs by $7,300. The all-electric 2021 IECC increases lifecycle costs by $6,200 over 7 years.

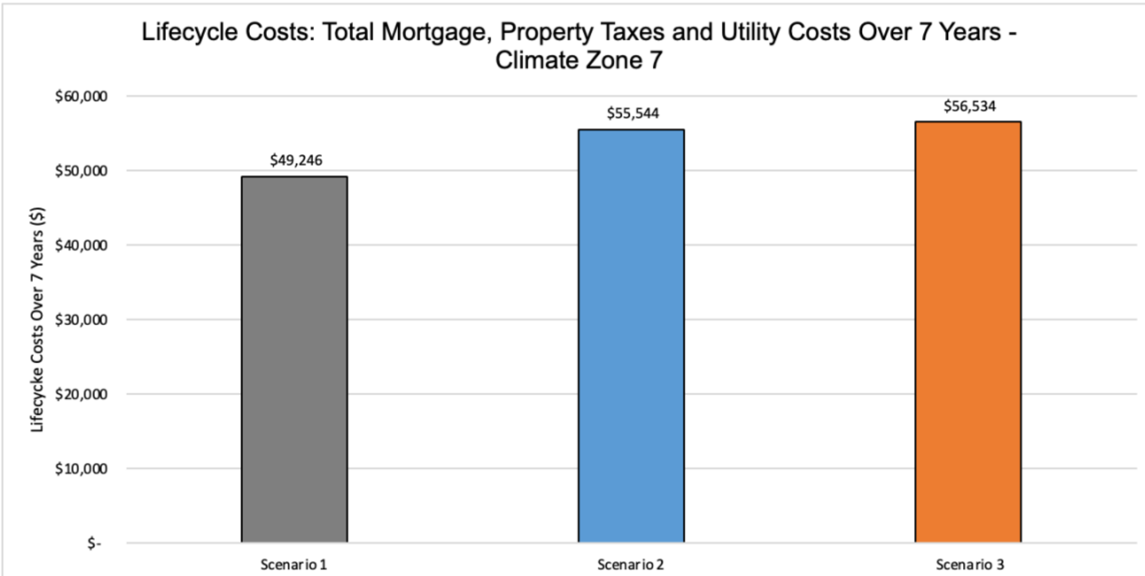

Figure 9: Lifecycle Costs for all scenarios in Climate Zone 7. Scenario 1 represents the current code baseline. Scenario 2 represents a home built to all-electric 2021 IECC standards. Scenario 3 represents a home built to all-electric 2021 IECC standards with increased air sealing and wall insulation.

Although the lifecycle costs are not competitive in Climate Zone 7, rising gas prices and declining electric appliance costs could make all-electric housing more cost-effective than mixed-fuel homes. **To ensure residents are prepared to transition to all-electric homes when affordable, Michigan should require Climate Zone 7 to build electric-ready homes.** Electric ready homes can still install gas appliances and leverage the currently lower gas utility costs, but the electric infrastructure will already be installed ensuring residents can have affordable retrofits to transition to all electric appliances when they are ready.

4. **Additional Benefits:** Although the all-electric scenarios in this analysis come at a premium compared to the mixed-fuel scenario in Climate Zone 7, there are many benefits to adopting all-electric that merit this investment. As laid out above, Climate Zone 7 can improve indoor air quality by eliminating gas appliances and adding mechanical ventilation. Climate Zone 7 can reduce moisture problems by increasing wall insulation and air sealing. Since Climate Zone 7 is considered a very cold climate, these amendments are most important to employ in this region. Finally, Climate Zone 7 will see greenhouse gas emission benefits as outlined above. This will help upper Michigan reduce its climate impacts and improve outdoor air quality.

EXHIBIT 7

1610 R St., Suite 200, Sacramento, CA 95811

Impact of 2021 IECC on 2015 Michigan Residential Code

Prepared for:

Home Builders Association of Michigan
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Introduction

The energy efficiency of single-family residential construction in Michigan is governed by the Chapter 11 of the 2015 Michigan Residential Code ("Chapter 11"). Chapter 11 closely follows the 2012 IECC – Residential Provisions ("2012 IECC") with Michigan specific amendments. The 2012 IECC has been updated, with the current version being the 2021 IECC. The analysis in this report looks at the cost implications of the potential adoption of the requirements of the 2021 IECC in place of Chapter 11 of the 2015 Michigan Residential Code ("MRC")

This analysis models the energy use of a single-story and a two-story single-family home in each of Michigan's 3 IECC climate zones (CZs 5A, 6A, and 7) to calculate the initial costs, utility bill reductions, and payback period of the significant changes between the current code and the 2021 IECC.

Building Models

The buildings were modeled using BEopt[1], a software tool created by the National Renewable Energy Lab (NREL) to help optimize building energy efficiency. The software uses the EnergyPlus[2] simulation engine developed by the Department of Energy. In CZs 5A and 6A, the buildings are modeled with a finished basement, and in CZ 7 they are modeled with a crawl space. The base case buildings designed to comply with the prescriptive requirements of Chapter 11 and are mixed fuel with gas water heaters and gas furnaces for space heating. Energy costs are modeled using the state average costs, which are 16.3c/kWh for electricity[3] and 80c/therm for gas[4].

Single-story

The single-story building has 1260 sqft of conditioned space on the first floor, with a typical vented attic above.

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[1] https://www.nrel.gov/buildings/beopt.html
[2] https://energyplus.net/
[3] https://www.eia.gov/electricity/data/browser/#/topic/7?agg=0,1&geo=00004&endsec=o&linechart=ELEC.PRICE.MI-ALL.A&columnchart=ELEC.PRICE.MI-ALL.A&map=ELEC.PRICE.MI-ALL.A&freq=A&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&maptype=0
[4] https://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PRS_DMcf_a.htm

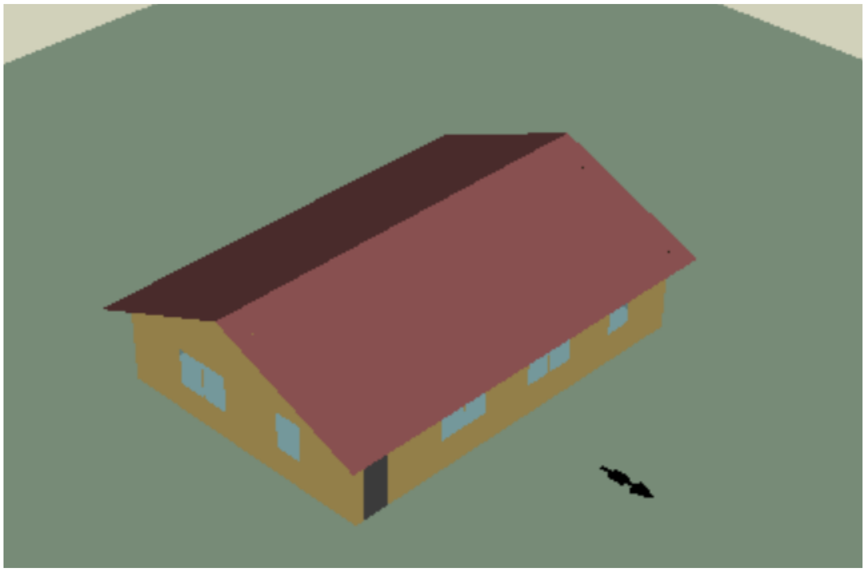

Figure 1: Perspective view of single-story building model

Two-story

The two-story building is modeled with 1998 sqft of living space over two floors. The first floor has 729 sqft of living space and a 540 sqft attached garage built on a slab. The second floor has a further 1269 sqft of living space below a standard vented attic.

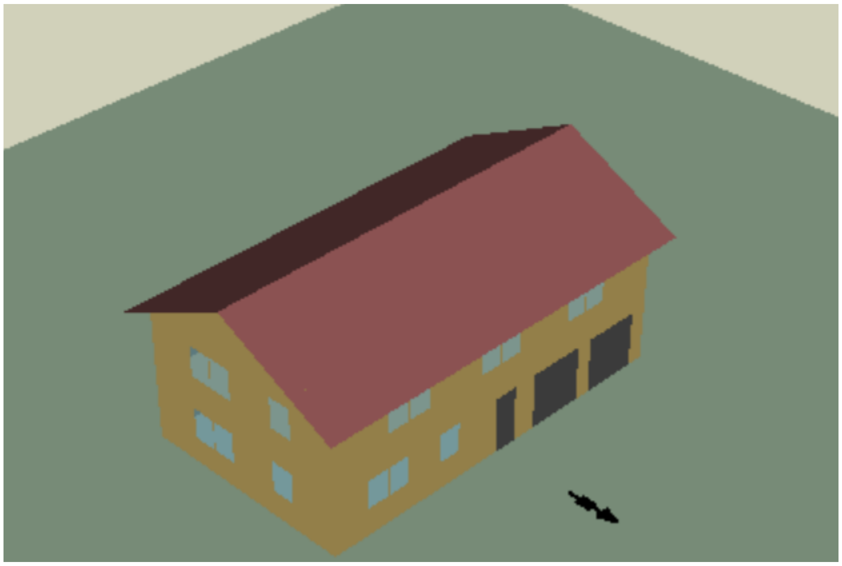

Figure 2: Perspective view of two-story building model

Weather Files

For each CZ the buildings are modeled using EnergyPlus weather files, which are the standard weather files used for building energy modeling. They use historical weather data which is aggregated to create a dataset representing a typical year. For this analysis, ConSol used weather files for the locations shown in Table 1 below

Climate Zone	Location
5A	Kent County Airport, Grand Rapids
6A	Roscommon County Airport, Houghton Lake
7	Chippewa County International Airport

Table 1: Weather file location

2021 IECC Changes

The prescriptive values in the 2021 IECC have higher efficiencies than Chapter 11 for several aspects of the building envelope. The changes from Chapter 11 required are different for the different CZs, which will lead to different costs and benefits. For example, Chapter 11 has a prescriptive ceiling insulation value for vented attics of R-38 in CZ 5A and R-49 in CZs 6A and 7, whereas the 2021 IECC has a prescriptive ceiling insulation level of R-60 for all three CZs. So buildings in CZ 5A will require twice as much additional insulation as those in CZs 6A and 7.

The changes modeled in this report are those shown in the table below, with the cost of each change shown for each house type and CZ. Costs are based on figures calculated by NREL, and ConSol's own cost database which uses costs provided by multiple sources in the building industry

Climate Zone	Stories	Item	Chapter 11 Value	2021 IECC Value	Cost
5	1	Wall insulation	R-20	R-20 + R-5 CI[5]	$668
		Attic insulation	R-38	R-60 Attic	$1,114
		Finished basement insulation	R-13	R-19	$585
		Window u-factor	0.32	0.30	$0
		Air leakage rate	4ACH50	3ACH50	$74
	2	Wall insulation	R-20	R-20 + R-5 CI	$1,063
		Attic insulation	R-38	R-60	$1,122
		Finished basement insulation	R-13	R-19	$439
		Window u-factor	0.32	0.30	$0
		Air leakage rate	4ACH50	3ACH50	$118
6/7	1	Wall insulation	R-20	R-20 + R-5 CI	$668
		Attic insulation	R-49	R-60	$551
		Window u-factor	0.32	0.30	$0
		Air leakage rate	4ACH50	3ACH50	$74
	2	Wall insulation	R-20	R-20 + R-5 CI	$1,063
		Attic insulation	R-49	R-60	$555
		Window u-factor	0.32	0.30	$0
		Air leakage rate	4ACH50	3ACH50	$118

Table 2: IECC 2021 upgrades

[5] R-20 + R-5 CI indicates a wall with R-20 cavity insulation and R-5 sheathing

Additional Efficiency Package Options

In addition to the individual measures listed above, the 2021 IECC prescriptively requires an additional efficiency package option. The options available are as follows:

1) Enhanced envelope performance option: the total building thermal envelope UA (the sum of the U-factor[6] times the area for each envelope element) must be less than or equal to 95% of the UA that would result from prescriptive values. The requirements of this option could be met by increasing the R-value of each of the envelope components by 5%, or by increasing some by more than 5% and others by less. Given the multiple pathways for meeting this requirement, and the need for an individual calculation that would be required for each building design, this option is not modeled in this report
2) Efficient HVAC option: the heating and cooling equipment used must meet minimum enhanced levels of efficiency:
    a. 95 AFUE furnace and 16 SEER AC for mixed fuel homes
    b. 10 HSPF/16 SEER air source heat pump or
    c. 3.5 COP ground source heat pump for electrically heated homes
3) Efficient water heating system: the water heater must meet minimum enhanced levels of efficiency:
    a. Greater than or equal to 0.82 EF fossil fuel service water-heating system.
    b. Greater than or equal to 2.0 EF electric service water-heating system.
    c. Greater than or equal to 0.4 solar fraction solar water-heating system.
4) More efficient duct thermal distribution system: 100% of ducts and air handlers, or ductless distribution systems located in conditioned space
5) Improved air sealing and ventilation: the building envelope leakage rate must be less than 3ACH50, and a heat or energy recovery ventilation system with a minimum sensible recovery efficiency of 75% must be installed

[6] The U-factor is the inverse of the R-value

Results

For each building type (single story and two story) and each climate zone, models were run to find the impact of each of the changes in the 2021 IECC for each of the additional efficiency packages. Models were run to show the cost and utility bill reduction for each individual change as well as the combined effect.

The tables below show the effect of the combined changes. Tables showing the individual changes are provided in Appendix A. Abbreviations in the table are:

DCS – Ducts in Conditioned Space
HE HVAC – High efficiency furnace and air conditioner
HE Water Heater – High efficiency water heater, modeled as a tankless gas water heater
HRV – Heat or energy recovery ventilation system

Climate Zone 5A

Single-story

Additional Efficiency Package	Initial Cost	Utility Bill Reduction	Simple Payback (years)
None	$2,442	$75	33
DCS	$2,627	$87	30
HE HVAC	$2,516	$138	18
HE Water Heater	$2,915	$105	28
HRV	$3,660	$57	64

Two-story

Additional Efficiency Package	Initial Cost	Utility Bill Reduction	Simple Payback (years)
None	$2,742	$108	25
DCS	$2,967	$116	26
HE HVAC	$3,649	$193	19
HE Water Heater	$3,215	$141	23
HRV	$3,669	$61	60

Climate Zone 6A

Single-story

Additional Efficiency Package	Initial Cost	Utility Bill Reduction	Simple Payback (years)
None	$1,293	$54	24
DCS	$1,478	$70	21
HE HVAC	$2,202	$125	18
HE Water Heater	$1,766	$82	22
HRV	$2,262	$43	53

Two-story

Additional Efficiency Package	Initial Cost	Utility Bill Reduction	Simple Payback (years)
None	$1,736	$100	17
DCS	$1,961	$118	17
HE HVAC	$2,645	$196	13
HE Water Heater	$2,209	$130	17
HRV	$2,666	$66	40

Climate Zone 7

Single-story

Additional Efficiency Package	Initial Cost	Utility Bill Reduction	Simple Payback (years)
None	$2,143	$60	36
DCS	$2,328	$131	18
HE HVAC	$3,052	$130	23
HE Water Heater	$2,616	$69	38

Two-story

Additional Efficiency Package	Initial Cost	Utility Bill Reduction	Simple Payback (years)
None	$2,578	$92	28
DCS	$2,733	$155	18
HE HVAC	$3,495	$196	18
HE Water Heater	$3,059	$105	29

Appendix A

The tables here provide detail of the cost and energy savings for each individual change between Chapter 11 and the 2021 IECC.

Climate Zone 5A, single-story:

Efficiency Package Option	Code Upgrade	Incremental Cost	Utility Bill Reduction	Simple Payback (years)
None	None			
	Wall insulation	$668	$28	24
	Attic insulation	$1,114	$22	51
	Finished basement insulation	$585	$11	53
	Window u-factor	$0	$6	Immediate
	Air leakage rate	$75	$11	7
	All	$2,442	$75	33
DCS	None	$185	$22	8
	Wall insulation	$668	$48	14
	Attic insulation	$1,114	$43	26
	Finished basement insulation	$585	$33	18
	Window u-factor	$0	$27	Immediate
	Air leakage rate	$75	$31	2
	All	$2,627	$87	30
HE HVAC	None	$909	$78	12
	Wall insulation	$668	$102	7
	Attic insulation	$1,114	$98	11
	Finished basement insulation	$585	$87	7
	Window u-factor	$0	$83	Immediate
	Air leakage rate	$75	$86	1
	All	$2,516	$138	18
HE Water Heater	None	$473	$31	15
	Wall insulation	$668	$59	11
	Attic insulation	$1,114	$52	21
	Finished basement insulation	$585	$42	14
	Window u-factor	$0	$36	Immediate
	Air leakage rate	$75	$41	2
	All	$2,915	$105	28
HRV	None	$1,293	-$6	Payback Not Possible[i]
	Wall insulation	$668	$21	32
	Attic insulation	$1,114	$14	80
	Finished basement insulation	$585	$5	117
	Window u-factor	$0	-$1	Immediate
	All	$3,660	$57	64

Climate Zone 5A, two-story

Efficiency Package Option	Code Upgrade	Incremental Cost	Utility Bill Reduction	Simple Payback (years)
None	None			
	Wall insulation	$1,063	$34	31
	Attic insulation	$1,122	$17	66
	Finished basement insulation	$439	$4	110
	Window u-factor	$0	$4	Immediate
	Air leakage rate	$118	$34	3
	All	$2,742	$108	25
DCS	None	$225	$22	10
	Wall insulation	$1,063	$55	19
	Attic insulation	$1,122	$35	32
	Finished basement insulation	$439	$22	20
	Window u-factor	$0	$22	Immediate
	Air leakage rate	$118	$48	2
	All	$2,967	$116	26
HE HVAC	None	$907	$100	9
	Wall insulation	$1,063	$133	8
	Attic insulation	$1,122	$116	10
	Finished basement insulation	$439	$106	4
	Window u-factor	$0	$107	Immediate
	Air leakage rate	$118	$133	1
	All	$3,649	$193	19
HE Water Heater	None	$473	$29	16
	Wall insulation	$1,063	$67	16
	Attic insulation	$1,122	$47	24
	Finished basement insulation	$439	$36	12
	Window u-factor	$0	$37	Immediate
	Air leakage rate	$118	$66	2
	All	$3,215	$141	23
HRV	None	$1,045	$3	348
	Wall insulation	$1,063	$38	28
	Attic insulation	$1,122	$11	102
	Finished basement insulation	$439	$6	73
	Window u-factor	$0	$14	Immediate
	All	$3,669	$61	60

Climate Zone 6A, single-story

Efficiency Package Option	**Code Upgrade**	**Incremental Cost**	**Utility Bill Reduction**	**Simple Payback (years)**
None	None			
	Wall insulation	$668	$30	22
	Attic insulation	$551	$9	61
	Window u-factor	$0	$6	Immediate
	Air leakage rate	$74	$9	8
	All	$1,293	$54	24
DCS	None	$185	$17	11
	Wall insulation	$668	$46	15
	Attic insulation	$551	$26	21
	Window u-factor	$0	$23	Immediate
	Air leakage rate	$74	$27	3
	All	$1,478	$70	21
HE HVAC	None	$909	$81	11
	Wall insulation	$668	$105	6
	Attic insulation	$551	$88	6
	Window u-factor	$0	$86	Immediate
	Air leakage rate	$74	$88	1
	All	$2,202	$125	18
HE Water Heater	None	$473	$28	17
	Wall insulation	$668	$58	12
	Attic insulation	$551	$37	15
	Window u-factor	$0	$34	Immediate
	Air leakage rate	$74	$38	2
	All	$1,766	$82	22
HRV	None	$1,043	-$2	Payback Not Possible
	Wall insulation	$668	$28	24
	Attic insulation	$551	$7	79
	Window u-factor	$0	$4	Immediate
	All	$2,262	$43	53

Climate Zone 6A, two-story

Efficiency Package Option	Code Upgrade	Incremental Cost	Utility Bill Reduction	Simple Payback (years)
None	None			
	Wall insulation	$1,063	$46	23
	Attic insulation	$555	$9	62
	Window u-factor	$0	$10	Immediate
	Air leakage rate	$118	$36	3
	All	$1,736	$100	17
DCS	None	$225	$20	11
	Wall insulation	$1,063	$66	16
	Attic insulation	$555	$30	19
	Window u-factor	$0	$30	Immediate
	Air leakage rate	$118	$56	2
	All	$1,961	$118	17
HE HVAC	None	$909	$114	8
	Wall insulation	$1,063	$152	7
	Attic insulation	$555	$121	5
	Window u-factor	$0	$123	Immediate
	Air leakage rate	$118	$143	1
	All	$2,645	$196	13
HE Water Heater	None	$473	$30	16
	Wall insulation	$1,063	$76	14
	Attic insulation	$555	$39	14
	Window u-factor	$0	$66	Immediate
	Air leakage rate	$118	$66	2
	All	$2,209	$130	17
HRV	None	$1,048	$4	262
	Wall insulation	$1,063	$49	22
	Attic insulation	$555	$12	46
	Window u-factor	$0	$14	Immediate
	All	$2,666	$66	40

Climate Zone 7, single-story

Efficiency Package Option	Code Upgrade	Incremental Cost	Utility Bill Reduction	Simple Payback (years)
None (No HRV)	None			
None (with HRV)	None	$850	-$2	Payback Not Possible
	Wall insulation	$668	$29	23
	Attic insulation	$551	$6	92
	Window u-factor	$0	$4	Immediate
	Air leakage rate	$74	$12	6
	All	$2,143	$60	36
DCS	None	$185	$70	3
	Wall insulation	$668	$100	7
	Attic insulation	$551	$79	7
	Window u-factor	$0	$77	Immediate
	Air leakage rate	$74	$86	1
	All	$1,478	$131	11
HE HVAC	None	$909	$80	11
	Wall insulation	$668	$105	6
	Attic insulation	$551	$87	6
	Window u-factor	$0	$85	Immediate
	Air leakage rate	$74	$91	1
	All	$2,202	$130	17
HE Water Heater	None	$473	$7	68
	Wall insulation	$668	$38	18
	Attic insulation	$551	$16	34
	Window u-factor	$0	$14	Immediate
	Air leakage rate	$74	$22	3
	All	$1,766	$69	26

Climate Zone 7, two-story

Efficiency Package Option	Code Upgrade	Incremental Cost	Utility Bill Reduction	Simple Payback (years)
None (No HRV)	None			
None (with HRV)	None	$842	-$14	Payback Not Possible
	Wall insulation	$1,063	$36	30
	Attic insulation	$555	-$4	Payback Not Possible
	Window u-factor	$0	-$3	Immediate
	Air leakage rate	$118	$23	5
	All	$2,578	$92	28
DCS	None	$147	$53	3
	Wall insulation	$1,063	$99	11
	Attic insulation	$555	$60	9
	Window u-factor	$0	$62	Immediate
	Air leakage rate	$118	$89	1
	All	$1,883	$155	12
HE HVAC	None	$909	$111	8
	Wall insulation	$1,063	$152	7
	Attic insulation	$555	$120	5
	Window u-factor	$0	$121	Immediate
	Air leakage rate	$118	$139	1
	All	$2,645	$196	13
HE Water Heater	None	$473	$0	Payback Not Possible
	Wall insulation	$1,063	$48	22
	Attic insulation	$555	$9	62
	Window u-factor	$0	$10	Immediate
	Air leakage rate	$118	$35	3
	All	$2,209	$105	21

[i] When the utility bill shows an increase rather than a reduction, this is a result of the HRV using more energy to run the fan than is saved through heat exchange between the incoming and outgoing airstreams. The energy savings due to heat exchange are proportional to the difference between the indoor and outdoor air temperatures while the fan energy use is a constant.

EXHIBIT 8

NAHB Priced-Out Estimates for 2022

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Special Study for Housing Economics
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Economics and Housing Policy
National Association of Home Builders

This article presents the NAHB's "priced out estimates" for 2022, showing how higher prices and interest rates affect housing affordability. The 2022 US estimates indicate that a $1,000 increase in the median new home price ($412,505[1]) would price 117,932 households out of the market. As a benchmark, 87.5 million households (roughly 69 percent of all U.S. households) are not able to afford a new median priced new home. A $1,000 home price increase would make 117,932 more households disqualify for the new home mortgage. Home prices surged during the pandemic, creating affordability challenges, particularly for first-time buyers.

Other NAHB estimates in this paper show that for 2022, 25 basis points added to the mortgage rate at 30-year fixed rate of 3.5% would price out around 1.1 million households. In addition to the national numbers, NAHB once again is providing priced out estimates for individual states and more than 300 metropolitan areas.

The Priced-Out Methodology and Data

The NAHB priced-out model uses the ability to qualify a mortgage to measure housing affordability, because most home buyers finance their new home purchase with conventional loans, and because convenient underwriting standards for these loans apply. The standard NAHB adopts for its priced-out estimates is that the sum of the mortgage payment (including the principal amount, loan interest, property tax, homeowners' property and private mortgage insurance premiums (PITI), is no more than 28 percent of monthly gross household income.

As a result, the number of households that qualify for mortgages for a certain priced home depends on the household income distribution in an area and the mortgage interest rate at that

[1] The 2022 US median new home price is estimated by projecting the 2021 preliminary median new home price using the NAHB forecast of the Case-Shiller Home Price Index.

time. The most recent detailed household income distributions for all states and metro areas are from the 2019[2] American Community Survey (ACS). NAHB adjusts the income distributions to reflect the income and population changes that may happen from 2019 to 2022. The income distribution is adjusted for inflation using the 2021 median family income at the state[3] and metro[4] levels and then extrapolated into 2022. The number of households in 2022 is projected by the growth rate of households from 2018 to 2019.

Other assumptions of the priced-out calculation include a 10% down payment and a 30-year fixed rate mortgage at an interest rate of 2.8% with zero points. For a loan with this down payment, private mortgage insurance is required by lenders and thus included as part of PITI. The typical private mortgage insurance annual premium is 73 basis points,[5] based on the standard assumption of a national median credit score of 738[6] and 10% down payment and 30-year fixed mortgage rate. Effective local property tax rates are calculated using data from the 2019 American Community Survey (ACS) summary files. Homeowner insurance rates are constructed from the 2019 ACS Public Use Microdata Sample (PUMS)[7]. For the US as a whole, the effective property tax rate is $10.7 per $1,000 of property value and typical homeowner insurance is $3.6 per $1,000 of property value.

U.S. Priced-Out Estimates

Under these assumptions, 39 million (about 31%) of the 126.7 million US households could afford to buy a new median priced home at $412,505 in 2022. A $1,000 home price increase will thus price 117,932 households out of the market for this home. These are the households that can qualify for a mortgage before a $1,000 increase but not afterwards, as shown in Table 1 below.

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[2] We used the standard 2019 1-year ACS data, because the experimental 2020 1-year ACS may have some potential issues on some estimates and also doesn't cover the metro level estimates due to the disruptions of data collection during the pandemic.
[3] The state median family income is published by Department of Housing and Urban Development (HUD).
[4] The MSA median family income is calculated by HUD and published by Federal Financial Institutions Examination Council (FFIEC).
[5] Private mortgage insurance premium (PMI) is obtained from the PMI Cost Calculator(https://www.hsh.com/calc-pmionly.html)
[6] Median credit score information is shown in the article "Four ways today's high home prices affect the larger economy" October 2018 Urban Institute https://www.urban.org/urban-wire/four-ways-todays-high-home-prices-affect-larger-economy
[7] Producing metro level estimates from the ACS PUMS involves aggregating Public Use Microdata Area (PUMA) level data according to the latest definitions of metropolitan areas. Due to complexity of these procedures and since metro level insurance rates tend to remain stable over time, NAHB revises these estimates only periodically.

Table 1. US Households Priced Out of the Market by Increases in House Prices, 2022

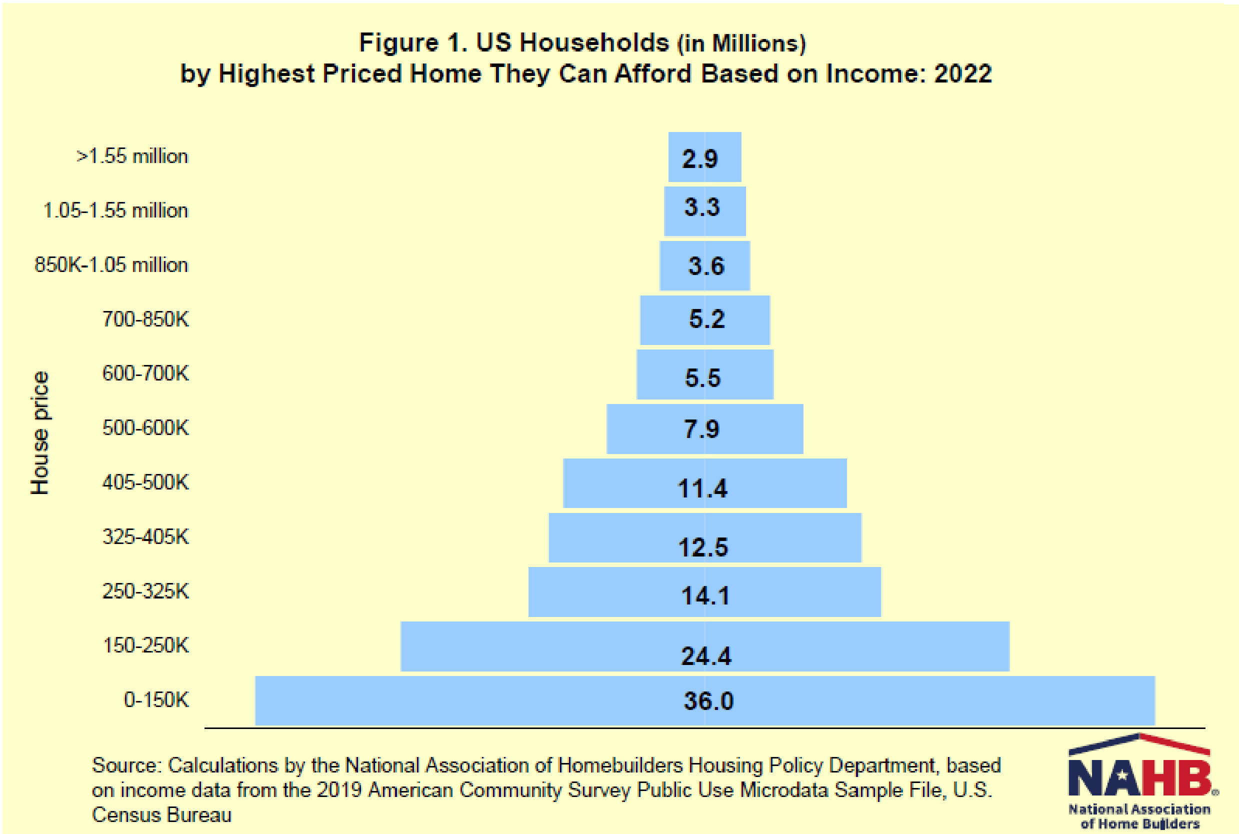
Area	Mortgage Rate	House Price	Monthly Mortgage Payment	Taxes and Insurance	Minimum Income Needed	Households That Can Afford House	Households That Cannot Afford House
United States	3.50%	$412,506	$1,822	$493	$99,205	39,205,292	87,527,382
United States	3.50%	$413,506	$1,826	$494	$99,445	39,087,360	87,645,314
Difference		$1,000	$4	$1	$240	-117,932	117,932

Calculations assume a 10% down payment and a 73 basis point fee for private mortgage insurance.
A Household Qualifies for a Mortgage if Mortgage Payments, Taxes, and Insurance are 28% of Income

US Household Income Distribution for 2022

Income Range:			Households	Cumulative
$0	to	$9,806	7,346,720	7,346,720
$9,807	to	$14,710	5,098,688	12,445,408
$14,711	to	$19,613	4,993,521	17,438,928
$19,614	to	$24,517	5,492,472	22,931,400
$24,518	to	$29,420	5,143,791	28,075,191
$29,421	to	$34,324	5,491,210	33,566,400
$34,325	to	$39,228	5,091,265	38,657,665
$39,229	to	$44,131	5,277,777	43,935,442
$44,132	to	$49,035	4,768,527	48,703,969
$49,036	to	$58,842	9,371,391	58,075,361
$58,843	to	$73,553	12,639,876	70,715,236
$73,554	to	$98,071	16,256,580	86,971,817
$98,072	to	$122,588	12,022,980	98,994,796
$122,589	to	$147,106	7,897,653	106,892,450
$147,107	to	$196,142	9,084,459	115,976,909
$196,143	to	More	10,755,766	126,732,674

The U.S. housing affordability pyramid represents the number of households that could only afford homes of no more than a certain price. Based on conventional assumptions and underwriting standards, the minimum income required to purchase a $150,000 home is $36,074. In 2022, about 36 million households in the U.S. are estimated to have incomes no more than that threshold and, therefore, can only afford to buy homes priced no more than $150,000. These 36 million households form the bottom step of the pyramid (Figure 1). Of the remaining households who can afford a home priced at $150,000, 24.4 million can only afford to pay a top price of somewhere between $150,000 and $250,000 (the second step on the pyramid). Each step represents a maximum affordable price range for fewer and fewer households. Housing affordability is a great concern for households with annual income at the lower end of the distribution.



State and Local Estimates

The number of priced out households varies across both states and metropolitan areas, largely affected by the sizes of local population and the affordability of new homes. The 2022 priced-out estimates for all states and the District of Columbia are shown in Table 2, which presents the projected 2022 median new home price estimates and the amount of income needed to qualify the mortgage, the number of households who can and who cannot afford the new homes, and the number of households could be priced out if price goes up by $1,000. Among all the states, California registered the largest number of households priced out of the market by a $1,000 increase in the median-priced home in the state (12,411), followed by Texas (11,108), and Florida (6,931), largely because these three states are the top three populous states. Households in California, where half of all new homes are sold for less than $543,767, need an annual income of at least $120,445 to qualify for a new home mortgage. Therefore, around 9.2 million households (68.9% of all households) in California do not earn enough income to qualify for new home loan initially. In contrast, households in West Virginia only need to have a household income of $69,855 to qualify new home loans. Only 34% of households in West Virginia (around 239,830 households) cannot afford new homes at the median price of $306,339 in 2022.

Table 3 shows the 2022 priced-out estimates for 387 metropolitan statistical areas. The metropolitan area with the largest priced out effect, in terms of absolute numbers, is New York-Newark-Jersey City, NY-NJ-PA, where 4,734 households will be disqualified for a new median-priced home if price goes up by $1,000. The Chicago-Naperville-Elgin, IL-IN-WI metro area registers the second largest number of priced-out households (4,273), followed by Philadelphia-Camden-Wilmington, PA-NJ-DE-MD metro area (3,235). Different impacts of adding $1,000 to a new home price are largely due to different sizes of metro population and the affordability of new homes to begin with. The largest priced-out effect is in the New York metro area, where the median priced new homes are only affordability to 14% of households, is largely because of its status of have the largest population size among all metro areas (6.6 million households). Compared to the New York metro, the populations in the Chicago and Houston metro areas are much smaller. The Chicago metro area only has half of the New York metro population and the Philadelphia metro area has 25%. However, median priced homes in Chicago or Philadelphia metro areas are relatively more affordable initially. Around 33% of households in Chicago and 45% households in Philadelphia metro area are capable of buying new median-priced homes there.

Interest Rates

The NAHB 2022 priced-out estimates also present how interest rates affect the number of households that would be priced out of the new home market. If mortgage interest rate increase, the monthly mortgage payments will rise as well and therefore higher household income thresholds are needed to qualify for a mortgage loan. Table 4 shows the number of households priced out of the market for a new median priced home at $412,505 by each 25 basis-point increase in interest rate from 1.5% to 9.5%. When interest rates increase from 1.75% to 2.00%, around 1.4 million households can no longer afford buying median-priced new homes. An increase from 3.00% to 3.25% prices approximately 1.5 million households out of the market. However, about 539,000 households would be squeezed out of the market if interest rate goes up to 9% from 8.75%. This diminishing effect happens because only a few households at the smaller end of household income distribution will be affected. In contrast, when interest rates are relatively low, a 25 basis-point increase would affect a larger number of households at the larger section of the income distribution.

Table 4. U.S. Households Priced Out of the Market by an Increase in Interest Rates, 2022

Mortgage Rate	Median New House Price	Monthly Mortgage Payment	Taxes and Insurance	Minimum Income Needed	Households That Can Afford House	Change in Households	Cumulative Change
1.50%	$412,505	$1,415	$493	$81,775	50,566,246		
1.75%	$412,505	$1,463	$493	$83,820	49,210,076	-1,356,170	-1,356,170
2.00%	$412,505	$1,512	$493	$85,905	47,827,984	-1,382,092	-2,738,262
2.25%	$412,505	$1,561	$493	$88,028	46,420,275	-1,407,709	-4,145,971
2.50%	$412,505	$1,612	$493	$90,189	44,987,280	-1,432,995	-5,578,966
2.75%	$412,505	$1,663	$493	$92,388	43,529,350	-1,457,930	-7,036,896
3.00%	$412,505	$1,715	$493	$94,624	42,046,857	-1,482,493	-8,519,389
3.25%	$412,505	$1,768	$493	$96,896	40,540,195	-1,506,662	-10,026,051
3.50%	$412,505	$1,822	$493	$99,204	39,205,373	-1,334,822	-11,360,873
3.75%	$412,505	$1,877	$493	$101,548	38,056,255	-1,149,118	-12,509,991
4.00%	$412,505	$1,932	$493	$103,926	36,890,209	-1,166,046	-13,676,037
4.25%	$412,505	$1,988	$493	$106,337	35,707,574	-1,182,635	-14,858,672
4.50%	$412,505	$2,045	$493	$108,782	34,508,699	-1,198,875	-16,057,547
4.75%	$412,505	$2,103	$493	$111,259	33,293,939	-1,214,760	-17,272,307
5.00%	$412,505	$2,162	$493	$113,768	32,063,657	-1,230,282	-18,502,589
5.25%	$412,505	$2,221	$493	$116,308	30,818,224	-1,245,433	-19,748,022
5.50%	$412,505	$2,281	$493	$118,878	29,558,014	-1,260,210	-21,008,232
6.00%	$412,505	$2,403	$493	$124,105	27,249,752	-2,308,262	-23,316,494
6.25%	$412,505	$2,465	$493	$126,760	26,394,326	-855,426	-24,171,920
6.50%	$412,505	$2,528	$493	$129,443	25,530,198	-864,128	-25,036,048
6.75%	$412,505	$2,591	$493	$132,152	24,657,622	-872,576	-25,908,624
7.00%	$412,505	$2,655	$493	$134,886	23,776,850	-880,772	-26,789,396
7.25%	$412,505	$2,719	$493	$137,645	22,888,135	-888,715	-27,678,111
7.50%	$412,505	$2,784	$493	$140,428	21,991,728	-896,407	-28,574,518
7.75%	$412,505	$2,849	$493	$143,234	21,087,877	-903,851	-29,478,369
8.00%	$412,505	$2,915	$493	$146,062	20,176,829	-911,048	-30,389,417
8.25%	$412,505	$2,982	$493	$148,912	19,505,842	-670,987	-31,060,404
8.50%	$412,505	$3,049	$493	$151,783	18,974,005	-531,837	-31,592,241
8.75%	$412,505	$3,116	$493	$154,674	18,438,444	-535,561	-32,127,802
9.00%	$412,505	$3,184	$493	$157,584	17,899,294	-539,150	-32,666,952
9.25%	$412,505	$3,253	$493	$160,513	17,356,685	-542,609	-33,209,561
9.50%	$412,505	$3,321	$493	$163,460	16,810,748	-545,937	-33,755,498

Table 2 Households Priced Out of the Market by a $1,000 Price Increase, 2022

State	Median New Home Price	Income Needed to Qualify	Households: All	Households: Who Can Afford Median Price	Households: Who Can't Afford Median Price	Households: Priced Out
United States	412,505	99,205	126,732,674	39,205,292	87,527,382	117,932
Alabama	389,820	87,513	2,030,653	585,268	1,445,385	2,019
Alaska	592,752	145,654	245,273	52,520	192,753	185
Arizona	464,413	102,987	2,846,208	738,906	2,107,302	2,417
Arkansas	397,926	92,827	1,185,825	247,459	938,366	1,323
California	543,767	120,445	13,418,516	4,171,589	9,246,927	12,411
Colorado	539,922	118,177	2,419,693	678,245	1,741,448	2,373
Connecticut	569,691	159,690	1,374,395	295,752	1,078,643	722
Delaware	214,329	47,202	403,160	258,871	144,289	694
District of Columbia	705,027	151,871	304,205	85,272	218,933	152
Florida	422,108	100,752	8,202,464	2,048,794	6,153,670	6,931
Georgia	356,743	84,551	4,005,751	1,449,552	2,556,199	4,851
Hawaii	856,262	176,306	496,603	87,242	409,361	200
Idaho	402,374	89,371	704,941	193,828	511,113	954
Illinois	365,711	102,703	4,869,434	1,490,121	3,379,313	5,726
Indiana	370,500	88,007	2,593,558	789,096	1,804,462	3,217
Iowa	371,169	97,601	1,347,055	390,191	956,864	1,943
Kansas	411,450	108,523	1,153,221	260,181	893,040	1,209
Kentucky	369,690	88,143	1,797,683	474,190	1,323,493	2,187
Louisiana	367,716	86,125	1,752,695	512,485	1,240,210	1,917
Maine	464,093	115,349	583,667	110,801	472,866	554
Maryland	371,232	88,336	2,259,582	1,121,922	1,137,660	2,813
Massachusetts	608,827	146,813	2,731,440	687,723	2,043,717	1,468
Michigan	350,069	89,906	4,007,356	1,241,683	2,765,673	5,445
Minnesota	411,914	100,952	2,309,096	797,198	1,511,898	2,520
Mississippi	327,125	79,616	1,075,406	307,232	768,174	1,125
Missouri	363,418	88,621	2,530,303	747,029	1,783,274	3,273
Montana	375,244	87,237	456,886	136,905	319,981	582
Nebraska	321,924	87,060	789,585	270,038	519,547	1,250
Nevada	438,564	95,031	1,185,810	356,167	829,643	1,462
New Hampshire	522,209	143,126	573,134	124,665	448,469	461
New Jersey	321,921	92,227	3,398,860	1,616,994	1,781,866	4,734
New Mexico	446,296	102,908	791,404	163,836	627,568	559
New York	526,661	136,643	7,691,427	1,742,276	5,949,151	5,455
North Carolina	369,458	85,781	4,152,837	1,308,399	2,844,438	5,019
North Dakota	386,330	94,304	336,340	118,726	217,614	411
Ohio	392,571	101,746	4,867,616	1,225,401	3,642,215	4,479
Oklahoma	397,634	99,038	1,525,067	339,386	1,185,681	1,290
Oregon	533,740	122,608	1,677,821	355,490	1,322,331	1,073
Pennsylvania	411,744	105,800	5,266,983	1,430,479	3,836,504	5,095
Rhode Island	485,255	126,065	408,982	87,707	321,275	307
South Carolina	398,515	90,074	2,126,954	591,748	1,535,206	2,514
South Dakota	332,563	83,931	380,080	124,008	256,072	536
Tennessee	390,969	89,349	2,815,746	787,785	2,027,961	3,343
Texas	395,451	107,240	10,639,459	2,814,421	7,825,038	11,108
Utah	462,359	100,782	1,102,553	370,426	732,127	1,164
Vermont	498,757	133,782	266,994	43,964	223,030	176
Virginia	352,164	80,457	3,241,321	1,546,335	1,694,986	3,871
Washington	565,613	130,409	3,046,029	739,860	2,306,169	2,182
West Virginia	306,339	69,855	708,937	239,830	469,107	1,037
Wisconsin	394,639	103,737	2,431,158	614,779	1,816,379	2,761
Wyoming	643,010	143,774	241,973	34,538	207,435	134

Table 3 Households Priced Out of the Market by a $1,000 Price Increase, 2022

Metro Area	Median New Home Price	Income Needed to Qualify	Households			
			All	Who Can Afford	Who Can't Afford	Priced Out
Abilene, TX	370,260	97,759	62,424	10,618	51,806	55
Akron, OH	620,647	163,679	281,497	40,328	241,169	130
Albany, GA	210,102	54,145	47,979	18,652	29,327	67
Albany-Lebanon, OR	477,331	114,312	52,348	5,477	46,871	32
Albany-Schenectady-Troy, NY	453,699	125,344	390,092	94,671	295,421	425
Albuquerque, NM	441,549	105,422	342,241	75,583	266,658	287
Alexandria, LA	408,861	95,832	57,007	13,234	43,773	47
Allentown-Bethlehem-Easton, PA-NJ	386,349	105,230	327,762	100,262	227,500	395
Altoona, PA	347,794	85,693	56,935	18,626	38,309	63
Amarillo, TX	417,714	115,424	98,870	21,387	77,483	102
Ames, IA	426,010	110,843	122,990	21,514	101,476	100
Anchorage, AK	616,135	153,196	139,296	28,178	111,118	120
Ann Arbor, MI	387,260	99,670	137,585	52,784	84,801	185
Anniston-Oxford, AL	249,778	57,517	45,771	20,351	25,420	84
Appleton, WI	395,745	104,592	95,319	25,559	69,760	116
Asheville, NC	475,109	105,580	198,214	44,588	153,626	142
Athens-Clarke County, GA	418,267	99,477	91,349	20,710	70,639	68
Atlanta-Sandy Springs-Alpharetta, GA	374,340	88,463	2,353,055	952,462	1,400,593	2,955
Atlantic City-Hammonton, NJ	464,630	143,861	118,554	24,662	93,892	78
Auburn-Opelika, AL	459,346	103,248	82,582	18,123	64,459	56
Augusta-Richmond County, GA-SC	328,711	76,632	205,682	81,080	124,602	312
Austin-Round Rock-Georgetown, TX	503,446	136,067	921,210	240,753	680,457	791
Bakersfield, CA	468,706	110,346	272,053	55,414	216,639	233
Baltimore-Columbia-Towson, MD	370,465	88,708	1,089,357	522,845	566,512	1,319
Bangor, ME	401,583	102,531	71,630	10,161	61,469	72
Barnstable Town, MA	923,338	213,849	133,245	(3,836)	137,081	77
Baton Rouge, LA	383,656	89,358	317,547	98,014	219,533	397
Battle Creek, MI	326,691	86,334	53,567	11,669	41,898	78
Bay City, MI	337,186	105,195	46,165	7,114	39,051	51
Beaumont-Port Arthur, TX	313,411	86,917	133,516	35,677	97,839	205
Beckley, WV	242,427	56,167	50,601	18,925	31,676	64
Bellingham, WA	555,365	124,815	94,141	13,143	80,998	62
Bend, OR	617,944	137,621	67,116	10,451	56,665	37
Billings, MT	332,173	78,598	100,611	39,283	61,328	108
Binghamton, NY	314,801	96,331	110,794	27,848	82,946	180
Birmingham-Hoover, AL	482,037	108,820	407,863	94,362	313,501	361
Bismarck, ND	439,498	105,819	42,050	13,577	28,473	50
Blacksburg-Christiansburg, VA	336,030	76,244	46,490	15,710	30,780	96
Blacksburg-Christiansburg, VA	336,030	76,244	46,490	15,710	30,780	96
Bloomington, IL	314,387	92,786	45,136	14,960	30,176	75
Bloomington, IN	361,796	85,128	53,191	13,354	39,837	74
Bloomsburg-Berwick, PA	400,528	100,008	31,634	9,110	22,524	41
Boise City, ID	475,590	105,816	299,102	72,774	226,328	277
Boston-Cambridge-Newton, MA-NH	659,214	159,304	1,879,865	517,553	1,362,312	1,060
Boulder, CO	807,426	174,316	143,134	33,245	109,889	61
Bowling Green, KY	358,988	84,324	63,108	18,033	45,075	71
Bremerton-Silverdale-Port Orchard, WA	596,700	136,959	114,125	25,802	88,323	87
Bridgeport-Stamford-Norwalk, CT	969,197	256,114	325,769	32,051	293,718	189
Brownsville-Harlingen, TX	205,709	58,960	143,787	48,265	95,522	243
Brunswick, GA	478,163	112,909	49,150	9,656	39,494	32
Buffalo-Cheektowaga, NY	560,710	162,718	516,476	53,651	462,825	202
Burlington, NC	285,358	66,161	63,178	25,320	37,858	137
Burlington-South Burlington, VT	557,489	145,847	97,897	15,842	82,055	42
California-Lexington Park, MD	409,726	97,025	37,684	20,843	16,841	41
Canton-Massillon, OH	339,446	86,352	172,156	49,055	123,101	223
Cape Coral-Fort Myers, FL	368,241	88,990	304,576	92,085	212,491	451

Table 3 Households Priced Out of the Market by a $1,000 Price Increase, 2022

Metro Area	Median New Home Price	Income Needed to Qualify	Households			
			All	Who Can Afford	Who Can't Afford	Priced Out
Cape Girardeau, MO-IL	378,262	89,998	52,532	8,451	44,081	53
Carbondale-Marion, IL	185,141	51,481	75,999	32,482	43,517	165
Carson City, NV	457,059	95,996	21,555	6,546	15,009	23
Casper, WY	409,649	92,312	35,578	12,264	23,314	49
Cedar Rapids, IA	235,396	62,608	122,486	69,918	52,568	249
Chambersburg-Waynesboro, PA	406,228	100,082	61,556	12,378	49,178	68
Champaign-Urbana, IL	380,765	108,313	68,992	16,316	52,676	61
Charleston, WV	166,635	39,099	192,163	114,037	78,126	365
Charleston-North Charleston, SC	444,796	100,016	334,532	100,413	234,119	343
Charlotte-Concord-Gastonia, NC-SC	406,068	93,525	1,051,128	317,963	733,165	984
Charlottesville, VA	436,512	98,832	82,950	25,978	56,972	86
Chattanooga, TN-GA	345,597	80,807	228,491	81,601	146,890	356
Cheyenne, WY	376,930	85,191	48,587	18,634	29,953	72
Chicago-Naperville-Elgin, IL-IN-WI	385,284	107,672	3,542,395	1,168,740	2,373,655	4,273
Chico, CA	451,705	102,054	52,210	10,886	41,324	47
Cincinnati, OH-KY-IN	359,070	91,187	928,803	300,805	627,998	1,118
Clarksville, TN-KY	232,271	55,244	154,298	74,661	79,637	305
Cleveland, TN	333,474	76,845	47,413	12,665	34,748	74
Cleveland-Elyria, OH	414,850	113,218	892,689	198,729	693,960	793
Coeur d'Alene, ID	497,238	108,535	66,277	7,515	58,762	30
College Station-Bryan, TX	333,039	89,362	94,543	28,536	66,007	141
Colorado Springs, CO	644,030	141,936	288,402	44,036	244,366	116
Columbia, MO	385,849	93,405	109,445	31,836	77,609	155
Columbia, SC	358,760	82,576	326,878	101,515	225,363	425
Columbus, GA-AL	228,129	55,001	136,505	62,040	74,465	242
Columbus, IN	343,559	81,094	26,274	8,646	17,628	54
Columbus, OH	398,828	103,510	864,699	251,794	612,905	969
Corpus Christi, TX	418,311	118,371	129,850	19,357	110,493	100
Corvallis, OR	532,862	125,183	43,556	8,741	34,815	35
Crestview-Fort Walton Beach-Destin, FL	638,703	148,742	87,046	10,590	76,456	23
Cumberland, MD-WV	385,887	91,418	32,371	5,003	27,368	45
Dallas-Fort Worth-Arlington, TX	445,150	122,350	2,668,719	763,144	1,905,575	2,800
Dalton, GA	245,341	57,425	48,066	20,374	27,692	95
Danville, IL	246,170	70,123	34,316	11,216	23,100	60
Daphne-Fairhope-Foley, AL	409,307	90,223	78,895	23,765	55,130	97
Davenport-Moline-Rock Island, IA-IL	312,842	87,089	160,052	51,906	108,146	241
Decatur, AL	364,671	82,853	63,893	18,964	44,929	68
Decatur, IL	380,970	106,780	37,712	4,631	33,081	40
Deltona-Daytona Beach-Ormond Beach, FL	485,316	115,511	276,985	45,011	231,974	217
Denver-Aurora-Lakewood, CO	619,950	136,810	1,217,976	323,273	894,703	911
Des Moines-West Des Moines, IA	399,241	107,783	370,747	105,957	264,790	450
Detroit-Warren-Dearborn, MI	382,726	98,852	1,750,729	508,048	1,242,681	1,735
Dothan, AL	409,015	91,859	61,092	15,133	45,959	63
Dover, DE	289,057	63,009	68,572	31,760	36,812	124
Dubuque, IA	420,038	109,329	37,881	8,400	29,481	39
Duluth, MN-WI	293,191	72,605	151,133	54,713	96,420	219
Durham-Chapel Hill, NC	403,951	95,244	369,332	117,983	251,349	484
East Stroudsburg, PA	473,477	138,179	59,919	12,252	47,667	52
Eau Claire, WI	383,493	98,953	68,004	17,713	50,291	85
El Centro, CA	373,511	87,749	73,983	18,427	55,556	93
Elizabethtown-Fort Knox, KY	336,249	79,983	63,304	17,208	46,096	77
Elkhart-Goshen, IN	347,842	82,359	55,260	13,576	41,684	74
Elmira, NY	333,791	100,836	31,105	6,787	24,318	34
El Paso, TX	414,875	121,837	267,203	23,615	243,588	116
Enid, OK	611,310	156,209	25,863	1,195	24,668	7
Erie, PA	391,807	105,418	111,127	18,258	92,869	114

Table 3 Households Priced Out of the Market by a $1,000 Price Increase, 2022

			Households			
Metro Area	**Median New Home Price**	**Income Needed to Qualify**	**All**	**Who Can Afford**	**Who Can't Afford**	**Priced Out**
Eugene-Springfield, OR	484,241	112,537	154,573	24,704	129,869	143
Evansville, IN-KY	423,341	102,044	133,922	33,573	100,349	180
Fairbanks, AK	656,901	164,416	33,200	7,091	26,109	15
Fargo, ND-MN	396,228	99,032	119,902	34,882	85,020	157
Farmington, NM	436,529	99,068	39,300	7,951	31,349	26
Fayetteville, NC	333,142	82,321	447,518	110,395	337,123	551
Fayetteville-Springdale-Rogers, AR	460,194	106,625	172,998	38,180	134,818	147
Fayetteville-Springdale-Rogers, AR	460,194	106,625	172,998	38,180	134,818	147
Flagstaff, AZ	438,500	94,920	54,531	17,031	37,500	51
Flint, MI	321,404	85,821	168,583	45,923	122,660	210
Florence, SC	256,906	58,043	84,243	36,438	47,805	147
Florence-Muscle Shoals, AL	210,272	47,895	63,635	32,722	30,913	160
Fond du Lac, WI	437,776	115,892	47,771	5,007	42,764	51
Fort Collins, CO	527,405	115,120	170,752	45,447	125,305	161
Fort Smith, AR-OK	329,273	77,137	72,539	17,040	55,499	77
Fort Wayne, IN	372,538	89,282	129,584	36,235	93,349	167
Fresno, CA	584,761	134,146	336,158	43,725	292,433	145
Gadsden, AL	209,631	47,701	44,662	24,190	20,472	74
Gainesville, FL	410,251	99,444	221,838	43,128	178,710	174
Gainesville, GA	366,597	85,536	67,567	25,918	41,649	77
Gettysburg, PA	362,831	94,068	36,214	11,337	24,877	66
Glens Falls, NY	441,248	119,282	59,093	11,679	47,414	60
Goldsboro, NC	294,732	72,913	46,906	11,388	35,518	70
Grand Forks, ND-MN	348,302	86,027	50,039	14,336	35,703	66
Grand Island, NE	325,283	86,905	24,873	7,446	17,427	38
Grand Junction, CO	373,357	79,812	69,351	21,267	48,084	83
Grand Rapids-Kentwood, MI	367,825	91,458	395,458	118,360	277,098	611
Grand Rapids-Kentwood, MI	367,825	91,458	395,458	118,360	277,098	611
Grants Pass, OR	497,786	109,244	30,185	5,653	24,532	24
Great Falls, MT	450,976	109,521	25,795	3,666	22,129	18
Greeley, CO	456,657	100,415	122,049	44,315	77,734	137
Green Bay, WI	384,514	99,584	141,478	40,086	101,392	187
Greensboro-High Point, NC	386,866	91,613	299,819	81,678	218,141	340
Greenville, NC	374,077	90,924	76,076	15,346	60,730	76
Greenville-Anderson, SC	404,144	90,368	364,336	114,743	249,593	414
Gulfport-Biloxi, MS	324,706	79,714	171,894	47,367	124,527	208
Gulfport-Biloxi, MS	324,706	79,714	171,894	47,367	124,527	208
Hagerstown-Martinsburg, MD-WV	347,075	80,258	139,315	56,893	82,422	211
Hammond, LA	298,607	68,268	43,997	16,534	27,463	58
Hanford-Corcoran, CA	488,216	111,900	48,012	10,586	37,426	27
Harrisburg-Carlisle, PA	374,826	95,681	236,702	75,543	161,159	363
Harrisonburg, VA	466,109	104,015	44,529	8,528	36,001	41
Hartford-East Hartford-Middletown, CT	430,909	123,575	496,012	155,817	340,195	561
Hattiesburg, MS	331,821	81,449	77,482	22,297	55,185	54
Hickory-Lenoir-Morganton, NC	383,566	87,947	149,878	31,870	118,008	185
Hilton Head Island-Bluffton, SC	545,253	123,117	84,253	15,074	69,179	36
Hinesville, GA	345,070	85,591	26,330	5,032	21,298	36
Homosassa Springs, FL	333,217	79,016	71,371	13,907	57,464	100
Hot Springs, AR	400,506	92,273	46,022	11,667	34,355	36
Houma-Thibodaux, LA	411,906	95,482	87,329	26,471	60,858	93
Houston-The Woodlands-Sugar Land, TX	376,904	105,106	2,683,433	834,903	1,848,530	2,966
Huntington-Ashland, WV-KY-OH	249,429	58,891	136,441	56,025	80,416	249
Huntsville, AL	313,890	70,250	196,689	94,727	101,962	246
Idaho Falls, ID	356,957	80,508	53,623	19,907	33,716	71
Indianapolis-Carmel-Anderson, IN	404,891	96,718	825,931	238,887	587,044	777
Iowa City, IA	374,690	98,512	71,638	23,645	47,993	97

Table 3 Households Priced Out of the Market by a $1,000 Price Increase, 2022

Metro Area	Median New Home Price	Income Needed to Qualify	Households			
			All	Who Can Afford	Who Can't Afford	Priced Out
Ithaca, NY	463,846	137,763	40,539	7,126	33,413	24
Jackson, MI	284,020	73,544	57,953	14,618	43,335	126
Jackson, MS	425,861	103,169	247,128	53,040	194,088	184
Jackson, TN	374,772	90,509	189,959	39,996	149,963	183
Jacksonville, FL	350,907	83,189	612,100	225,298	386,802	834
Jacksonville, NC	250,034	60,538	54,821	25,743	29,078	113
Janesville-Beloit, WI	299,387	81,697	67,412	23,048	44,364	113
Jefferson City, MO	319,795	76,319	68,525	24,160	44,365	106
Johnson City, TN	324,625	74,167	100,725	27,527	73,198	96
Johnstown, PA	419,745	109,351	56,511	7,739	48,772	45
Jonesboro, AR	261,735	61,617	48,271	15,085	33,186	102
Joplin, MO	208,466	50,209	56,519	28,802	27,717	122
Kahului-Wailuku-Lahaina, HI	860,115	174,727	60,840	10,408	50,432	24
Kalamazoo-Portage, MI	340,703	89,565	48,379	15,765	32,614	70
Kankakee, IL	254,208	73,948	36,569	14,901	21,668	68
Kansas City, MO-KS	406,503	103,323	872,579	261,457	611,122	951
Kennewick-Richland, WA	569,733	132,312	110,899	22,629	88,270	80
Killeen-Temple, TX	310,708	85,798	172,850	46,540	126,310	260
Kingsport-Bristol, TN-VA	331,370	75,781	147,713	39,611	108,102	174
Kingston, NY	503,989	141,431	70,046	14,528	55,518	57
Knoxville, TN	359,502	81,161	357,924	107,482	250,442	481
Kokomo, IN	326,584	78,370	31,351	11,299	20,052	49
La Crosse-Onalaska, WI-MN	408,355	107,791	57,603	12,929	44,674	45
Lafayette, LA	332,491	77,517	184,181	63,713	120,468	229
Lafayette-West Lafayette, IN	350,480	81,946	117,680	35,963	81,717	118
Lake Charles, LA	296,693	69,613	76,922	30,979	45,943	101
Lake Havasu City-Kingman, AZ	364,962	80,352	93,616	22,344	71,272	107
Lakeland-Winter Haven, FL	336,604	80,168	231,163	70,568	160,595	288
Lancaster, PA	362,483	93,250	211,480	73,852	137,628	337
Lansing-East Lansing, MI	343,268	91,689	332,879	99,022	233,857	459
Laredo, TX	264,345	77,020	79,489	23,158	56,331	155
Las Cruces, NM	444,017	101,531	75,277	10,697	64,580	48
Las Vegas-Henderson-Paradise, NV	427,687	92,821	828,799	252,480	576,319	998
Lawrence, KS	488,696	126,480	47,330	7,403	39,927	30
Lawton, OK	310,252	78,670	42,706	15,595	27,111	59
Lebanon, PA	334,562	87,105	51,926	16,646	35,280	80
Lewiston, ID-WA	333,706	77,536	32,532	9,072	23,460	53
Lewiston-Auburn, ME	394,501	103,483	49,148	10,023	39,125	58
Lexington-Fayette, KY	393,855	93,338	210,462	58,692	151,770	273
Lima, OH	319,328	81,831	38,308	8,787	29,521	78
Lincoln, NE	341,637	92,054	142,430	46,638	95,792	189
Little Rock-North Little Rock-Conway, AR	380,758	90,676	301,484	85,219	216,265	341
Logan, UT-ID	399,881	89,613	50,275	15,604	34,671	68
Longview, TX	487,551	123,345	251,877	38,118	213,759	141
Longview, WA	481,870	110,966	41,356	8,583	32,773	29
Los Angeles-Long Beach-Anaheim, CA	827,177	181,947	4,428,273	475,469	3,952,804	2,063
Louisville/Jefferson County, KY-IN	329,897	78,521	460,321	171,654	288,667	608
Lubbock, TX	371,241	104,029	127,125	29,393	97,732	140
Lynchburg, VA	295,934	66,107	101,697	47,434	54,263	141
Macon-Bibb County, GA	301,272	76,810	89,437	24,508	64,929	125
Madera, CA	514,218	117,287	44,097	7,150	36,947	34
Madison, WI	458,221	120,626	289,531	71,378	218,153	358
Manchester-Nashua, NH	452,427	124,252	165,438	47,372	118,066	133
Manhattan, KS	418,768	108,437	101,173	17,231	83,942	118
Mankato, MN	341,398	83,818	41,418	13,131	28,287	71
Mansfield, OH	359,728	93,655	55,305	8,885	46,420	92

Table 3 Households Priced Out of the Market by a $1,000 Price Increase, 2022

Metro Area	Median New Home Price	Income Needed to Qualify	Households			
			All	Who Can Afford	Who Can't Afford	Priced Out
McAllen-Edinburg-Mission, TX	335,633	95,447	280,925	46,129	234,796	214
Medford, OR	515,510	117,083	82,099	14,693	67,406	56
Memphis, TN-MS-AR	377,236	92,760	507,779	132,324	375,455	639
Merced, CA	498,885	111,350	84,221	17,902	66,319	76
Miami-Fort Lauderdale-Pompano Beach, FL	540,455	131,314	2,325,093	300,137	2,024,956	840
Michigan City-La Porte, IN	392,072	94,563	43,034	11,641	31,393	46
Midland, MI	286,928	77,533	35,139	10,835	24,304	76
Midland, TX	287,752	73,390	67,505	34,192	33,313	85
Milwaukee-Waukesha, WI	516,115	134,610	638,219	106,816	531,403	445
Minneapolis-St. Paul-Bloomington, MN-WI	416,273	102,577	1,425,093	516,845	908,248	1,775
Missoula, MT	473,828	112,440	52,233	9,720	42,513	39
Mobile, AL	355,811	84,116	169,244	43,706	125,538	167
Modesto, CA	482,654	108,785	173,287	38,869	134,418	164
Monroe, LA	415,284	94,652	130,554	28,409	102,145	100
Monroe, MI	295,480	74,362	58,791	25,849	32,942	102
Montgomery, AL	391,315	87,155	153,087	43,901	109,186	148
Morgantown, WV	461,690	102,650	52,997	11,351	41,646	51
Morristown, TN	424,836	95,323	116,212	15,200	101,012	123
Mount Vernon-Anacortes, WA	566,632	131,062	50,790	11,191	39,599	45
Muncie, IN	337,031	83,071	46,641	10,293	36,348	54
Muskegon, MI	279,043	72,562	63,101	20,848	42,253	112
Myrtle Beach-Conway-North Myrtle Beach, SC-NC	322,745	72,444	234,589	78,923	155,666	303
Napa, CA	955,131	213,065	50,563	5,394	45,169	28
Naples-Marco Island, FL	664,399	152,806	130,325	23,840	106,485	48
Nashville-Davidson--Murfreesboro--Franklin, TN	450,473	100,736	743,099	199,878	543,221	773
Nashville-Davidson--Murfreesboro--Franklin, TN	450,473	100,736	743,099	199,878	543,221	773
New Bern, NC	334,683	80,343	61,798	18,997	42,801	74
New Haven-Milford, CT	356,202	103,077	310,160	107,378	202,782	435
New Orleans-Metairie, LA	405,482	96,947	493,842	121,453	372,389	444
New York-Newark-Jersey City, NY-NJ-PA	580,632	152,406	6,588,785	925,276	5,663,509	4,734
Niles, MI	459,927	114,827	53,681	11,565	42,116	46
North Port-Sarasota-Bradenton, FL	423,143	99,565	326,791	88,268	238,523	318
Norwich-New London, CT	453,563	124,261	114,867	27,142	87,725	103
Ocala, FL	241,760	57,169	152,366	59,109	93,257	300
Ocean City, NJ	723,202	183,868	46,604	4,650	41,954	22
Odessa, TX	417,120	107,602	49,791	15,082	34,709	51
Ogden-Clearfield, UT	439,004	96,586	242,488	91,400	151,088	381
Oklahoma City, OK	419,810	107,574	529,600	114,254	415,346	555
Olympia-Lacey-Tumwater, WA	512,298	120,206	119,762	27,892	91,870	97
Omaha-Council Bluffs, NE-IA	304,964	84,769	380,160	162,848	217,312	614
Orlando-Kissimmee-Sanford, FL	451,036	106,754	931,009	219,187	711,822	785
Oshkosh-Neenah, WI	412,357	111,134	70,957	14,753	56,204	69
Owensboro, KY	184,875	45,357	54,010	28,797	25,213	104
Oxnard-Thousand Oaks-Ventura, CA	850,049	188,244	258,417	34,422	223,995	146
Palm Bay-Melbourne-Titusville, FL	515,743	122,298	241,446	50,926	190,520	174
Panama City, FL	420,213	98,644	44,032	9,319	34,713	34
Parkersburg-Vienna, WV	364,812	83,976	31,423	7,367	24,056	39
Pensacola-Ferry Pass-Brent, FL	338,034	79,657	199,646	74,205	125,441	239
Peoria, IL	398,114	116,753	214,854	38,074	176,780	158
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	316,040	82,991	2,439,618	1,111,120	1,328,498	3,235
Phoenix-Mesa-Chandler, AZ	469,193	103,235	1,873,580	558,567	1,315,013	1,688
Pine Bluff, AR	222,306	52,250	40,396	18,972	21,424	101
Pittsburgh, PA	469,412	121,503	1,073,586	217,271	856,315	1,059
Pittsfield, MA	898,333	230,126	49,747	2,657	47,090	18
Pocatello, ID	294,905	69,237	49,503	17,209	32,294	92
Portland-South Portland, ME	518,287	126,714	222,919	51,470	171,449	238

Table 3 Households Priced Out of the Market by a $1,000 Price Increase, 2022

Metro Area	Median New Home Price	Income Needed to Qualify	Households All	Households Who Can Afford	Households Who Can't Afford	Households Priced Out
Portland-Vancouver-Hillsboro, OR-WA	562,869	130,113	993,959	264,234	729,725	748
Port St. Lucie, FL	385,506	94,265	182,142	46,276	135,866	205
Providence-Warwick, RI-MA	447,415	113,948	646,042	170,883	475,159	709
Provo-Orem, UT	509,321	109,368	207,750	62,694	145,056	235
Pueblo, CO	279,782	63,695	69,707	28,486	41,221	116
Punta Gorda, FL	453,087	110,329	81,642	14,753	66,889	70
Racine, WI	465,411	124,129	85,546	14,295	71,251	72
Raleigh-Cary, NC	396,699	91,299	566,682	234,573	332,109	724
Rapid City, SD	331,433	84,402	50,719	12,554	38,165	57
Reading, PA	348,083	96,074	147,968	50,112	97,856	220
Redding, CA	546,486	125,272	88,137	10,782	77,355	40
Reno, NV	541,426	116,667	207,147	47,077	160,070	227
Richmond, VA	354,759	81,438	475,681	190,350	285,331	569
Riverside-San Bernardino-Ontario, CA	526,128	120,388	1,419,316	332,681	1,086,635	1,442
Roanoke, VA	435,426	101,006	125,817	31,040	94,777	131
Rochester, MN	378,393	94,045	104,117	41,438	62,679	136
Rochester, NY	431,433	132,970	457,754	79,284	378,470	333
Rockford, IL	252,570	77,242	135,016	52,974	82,042	203
Rocky Mount, NC	243,946	60,234	57,602	26,885	30,717	110
Rome, GA	265,062	64,481	37,860	10,747	27,113	57
Sacramento-Roseville-Folsom, CA	555,470	126,259	913,341	236,878	676,463	608
Saginaw, MI	342,243	93,061	79,987	19,702	60,285	88
St. Cloud, MN	391,100	96,370	81,272	23,166	58,106	133
St. George, UT	487,715	104,865	74,106	13,397	60,709	86
St. Joseph, MO-KS	314,214	76,394	47,387	15,585	31,802	79
St. Louis, MO-IL	391,630	100,905	1,170,246	341,278	828,968	1,201
Salem, OR	526,042	122,524	157,050	18,368	138,682	121
Salinas, CA	895,680	196,860	134,189	14,702	119,487	45
Salisbury, MD-DE	305,135	67,176	184,584	75,464	109,120	243
Salt Lake City, UT	496,180	109,120	417,420	137,635	279,785	441
San Angelo, TX	371,639	98,822	46,885	7,270	39,615	75
San Antonio-New Braunfels, TX	408,809	111,254	851,058	196,793	654,265	885
San Diego-Chula Vista-Carlsbad, CA	859,869	190,812	1,137,015	164,077	972,938	499
San Francisco-Oakland-Berkeley, CA	1,368,671	300,883	1,791,189	201,279	1,589,910	838
San Jose-Sunnyvale-Santa Clara, CA	1,680,173	365,545	659,768	(87,851)	747,619	379
San Luis Obispo-Paso Robles, CA	795,842	175,539	107,460	14,735	92,725	47
Santa Cruz-Watsonville, CA	1,235,487	269,185	106,333	6,745	99,588	45
Santa Fe, NM	471,305	102,375	60,633	16,656	43,977	35
Santa Maria-Santa Barbara, CA	1,103,681	242,435	147,194	10,940	136,254	47
Santa Rosa-Petaluma, CA	800,537	177,657	200,797	38,354	162,443	93
Savannah, GA	389,233	95,203	141,594	45,903	95,691	172
Scranton--Wilkes-Barre, PA	429,585	115,213	237,810	46,031	191,779	183
Seattle-Tacoma-Bellevue, WA	721,105	166,017	1,587,245	405,415	1,181,830	773
Sebastian-Vero Beach, FL	643,032	152,270	87,173	13,536	73,637	44
Sebring-Avon Park, FL	361,939	87,451	52,879	7,734	45,145	45
Sheboygan, WI	428,302	113,987	56,601	11,219	45,382	48
Sherman-Denison, TX	351,588	93,874	49,207	13,307	35,900	67
Shreveport-Bossier City, LA	366,521	85,544	110,918	31,326	79,592	110
Sierra Vista-Douglas, AZ	289,944	67,303	59,293	26,928	32,365	75
Sioux City, IA-NE-SD	426,096	113,482	34,543	4,242	30,301	26
Sioux Falls, SD	303,918	76,517	123,464	52,776	70,688	168
South Bend-Mishawaka, IN-MI	323,581	78,268	119,823	42,820	77,003	175
Spartanburg, SC	263,206	59,944	103,927	50,480	53,447	218
Spokane-Spokane Valley, WA	476,798	111,950	232,486	45,006	187,480	185
Springfield, IL	387,104	109,394	88,674	21,713	66,961	107
Springfield, MA	498,605	130,530	401,606	73,736	327,870	312

Table 3 Households Priced Out of the Market by a $1,000 Price Increase, 2022

Metro Area	Median New Home Price	Income Needed to Qualify	Households			
			All	Who Can Afford	Who Can't Afford	Priced Out
Springfield, MO	332,335	79,710	215,500	62,305	153,195	236
Springfield, OH	375,992	98,598	51,734	11,468	40,266	64
State College, PA	482,051	115,729	60,331	13,898	46,433	47
Staunton, VA	296,950	66,668	54,579	21,533	33,046	90
Stockton, CA	570,800	130,165	225,285	46,115	179,170	148
Sumter, SC	220,783	51,776	154,141	65,333	88,808	413
Syracuse, NY	367,259	111,228	251,106	55,586	195,520	300
Tallahassee, FL	292,391	70,004	173,212	68,995	104,217	271
Tampa-St. Petersburg-Clearwater, FL	457,593	109,628	1,231,956	265,523	966,433	1,061
Terre Haute, IN	249,180	60,736	90,827	37,253	53,574	178
Texarkana, TX-AR	409,162	105,665	50,542	7,499	43,043	46
The Villages, FL	438,320	102,516	50,332	9,034	41,298	38
Toledo, OH	377,984	100,894	348,462	77,190	271,272	304
Topeka, KS	341,700	91,990	96,118	28,950	67,168	133
Trenton-Princeton, NJ	499,289	147,735	124,666	30,368	94,298	114
Tucson, AZ	526,703	123,022	435,634	58,977	376,657	240
Tulsa, OK	388,462	97,480	404,436	106,909	297,527	512
Tuscaloosa, AL	408,418	90,836	101,401	27,625	73,776	79
Twin Falls, ID	312,462	70,869	38,260	13,027	25,233	82
Tyler, TX	417,977	109,046	82,537	16,941	65,596	89
Urban Honolulu, HI	1,037,948	214,027	342,548	40,564	301,984	143
Utica-Rome, NY	504,421	148,836	125,738	11,972	113,766	47
Valdosta, GA	293,186	72,767	56,723	16,651	40,072	102
Vallejo, CA	583,628	132,015	144,840	41,689	103,151	117
Victoria, TX	415,035	113,414	27,052	6,839	20,213	37
Vineland-Bridgeton, NJ	437,866	133,563	55,553	7,617	47,936	33
Virginia Beach-Norfolk-Newport News, VA-NC	341,084	80,612	741,884	295,044	446,840	1,130
Visalia, CA	450,151	101,632	159,910	34,956	124,954	119
Waco, TX	382,704	103,693	103,766	17,561	86,205	93
Walla Walla, WA	555,347	131,491	21,119	3,292	17,827	13
Warner Robins, GA	324,690	79,578	61,379	21,434	39,945	98
Washington-Arlington-Alexandria, DC-VA-MD-WV	561,240	130,663	2,301,061	953,145	1,347,916	1,822
Waterloo-Cedar Falls, IA	365,773	97,317	63,531	16,051	47,480	76
Watertown-Fort Drum, NY	218,064	58,122	32,397	14,976	17,421	84
Wausau-Weston, WI	322,678	85,477	115,583	38,825	76,758	206
Wausau-Weston, WI	322,678	85,477	115,583	38,825	76,758	206
Weirton-Steubenville, WV-OH	304,703	73,914	45,517	12,174	33,343	68
Wenatchee, WA	459,733	105,208	35,711	8,914	26,797	29
Wheeling, WV-OH	401,218	94,620	67,228	13,084	54,144	62
Wichita, KS	379,695	101,277	241,039	53,028	188,011	282
Wichita Falls, TX	414,824	118,826	63,976	7,769	56,207	66
Williamsport, PA	398,239	103,078	45,622	10,077	35,545	65
Wilmington, NC	450,063	105,218	124,314	27,421	96,893	113
Winchester, VA-WV	380,749	84,516	40,527	15,866	24,661	66
Winston-Salem, NC	343,541	80,290	268,782	79,816	188,966	332
Worcester, MA-CT	451,937	114,678	394,154	122,450	271,704	447
Yakima, WA	444,935	103,927	86,041	13,031	73,010	77
York-Hanover, PA	354,219	95,887	179,966	56,761	123,205	288
Youngstown-Warren-Boardman, OH-PA	379,717	100,388	240,408	53,382	187,026	277
Yuba City, CA	500,426	115,355	65,223	13,420	51,803	64
Yuma, AZ	287,721	66,554	72,591	23,943	48,648	92

EXHIBIT 9

Minority Households Face Housing Affordability Challenges

BY **NA ZHAO** *on* **APRIL 13, 2021** • (**0**)

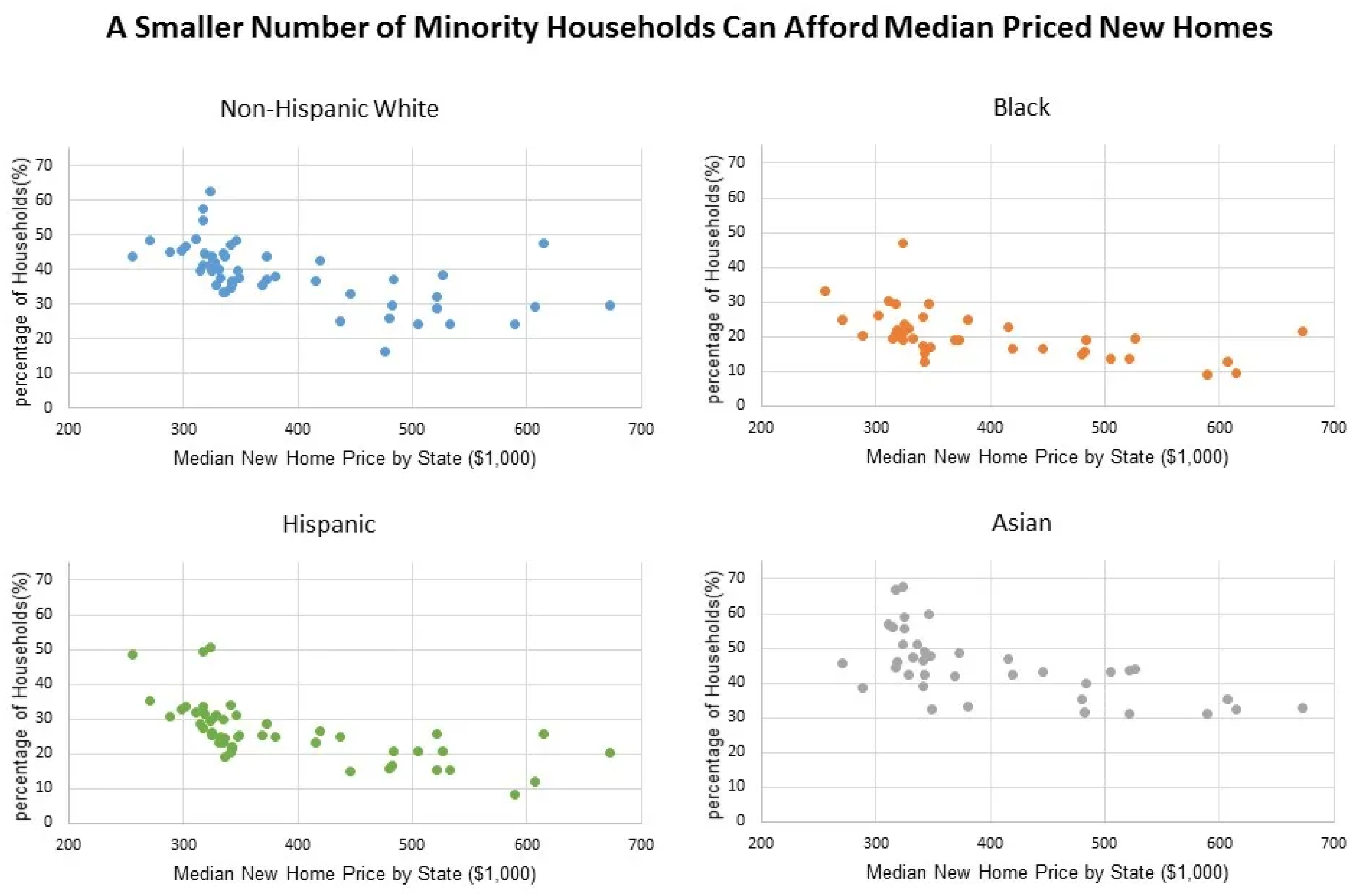
New NAHB analysis on housing affordability based on race and ethnicity shows a wide disparity regarding the number of households that can afford a new median priced home.

At the national level, the share Black households that are able to afford the new homes is substantially lower than the share of non-Hispanic white households. Only 24% of Black households are able to afford the median new U.S. price of $346,577. Among non-Hispanic white households, 44% have sufficient income to qualify for a mortgage for a new median priced home under standard underwriting criteria, compared to 56% of Asian households and 32% of Hispanic households.

The number of households being priced out of the market due to a $1,000 price increase varies among different racial/ethnical groups but is more or less proportional to population size. The largest priced-out number as a result of a $1,000 price increase is 106,278 for non-Hispanic white households, which accounts for around 67% of total U.S. households. By contrast, the number of Black and Hispanic households that would be priced out the market due to a $1,000 price hike are 15,840 and 21,376, respectively.

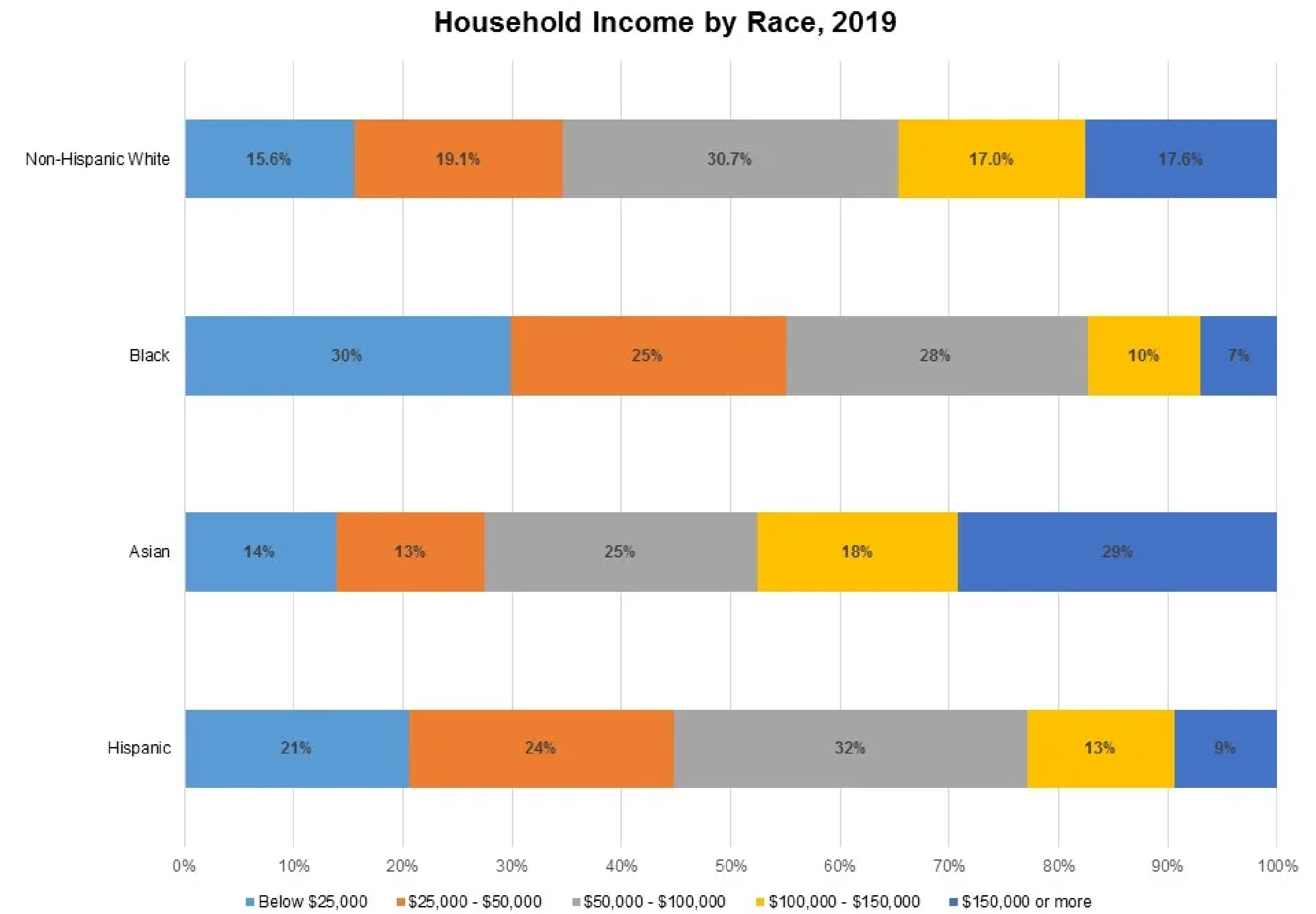
The affordability gaps between non-Hispanic white households and minority households are persistent across all states and are in fact larger in states where new home prices are relatively more affordable. The share of households that are able to afford new homes is largely affected by the state's median new home prices. And too often, more affordable markets does not mean that housing is equally affordable to all ethnic groups.

As indicated in the chart below, the higher the home price is, the smaller the number of households that can afford new homes. In Nebraska, where the median new price is $288,401, the share of non-Hispanic white households that could afford new homes is 25 percentage basis points larger than the share of Black households, and 14 percentage basis points larger than Hispanic households. However, this gap is much smaller in Hawaii, with a new median home price of $672,314. In Hawaii, 30% of non-Hispanic white households are able to qualify for a mortgage for a new median priced home, compared with 21% for Black households and 20% for Hispanic households.



Note: The scatterplot presents the median new home price and the percentage of households that can afford new homes for each state.
Source: NAHB tabulations of 2021 priced-out estimates at the state level

The housing affordability story is also a reflection of underlying income data. Income plays a key role in housing affordability, in terms of budget and mortgage qualification. According to the 2019 American Community Survey, the median household income for non-Hispanic white households was $71,664, significantly higher than the $43,862 for Black households. The differences of income distribution among race/ethnicity are large, as shown in the figure below. Thirty percent of Black households have household income below $25,000 compared to 15.5% of non-Hispanic white households. Around 17.6% of non-Hispanic white households earn more than $150,000 while only 7% of Black households do.



Source: NAHB estimates, 2019 American Community Survey

EXHIBIT 10

Michigan Office of Administrative Hearings and Rules

Administrative Rules Division (ARD)

MOAHR-Rules@michigan.gov

REGULATORY IMPACT STATEMENT and COST-BENEFT ANALYSIS (RIS)

Agency Information:

Department name:

Licensing and Regulatory Affairs

Bureau name:

Bureau of Construction Codes

Name of person filling out RIS:

Amanda Johnson

Phone number of person filling out RIS:

517-582-5519

E-mail of person filling out RIS:

JohnsonA39@michigan.gov

Rule Set Information:

ARD assigned rule set number:

2021-48 LR

Title of proposed rule set:

Construction Code - Part 10. Michigan Uniform Energy Code

Comparison of Rule(s) to Federal/State/Association Standard

1. Compare the proposed rules to parallel federal rules or standards set by a state or national licensing agency or accreditation association, if any exist.

There are no federal rules or standards set by a state or national licensing agency or accreditation association. The rules update the International Energy Conservation Code (IECC) code as required by 1972 PA 230, section 4(5).

A. Are these rules required by state law or federal mandate?

These rules are required by state law in MCL 125.1504(5), Stille- DeRossett-Hale Single Construction Code Act, 1972 PA 230. There are no federal mandates.

B. If these rules exceed a federal standard, please identify the federal standard or citation, describe why it is necessary that the proposed rules exceed the federal standard or law, and specify the costs and benefits arising out of the deviation.

There are no federal standards.

2. Compare the proposed rules to standards in similarly situated states, based on geographic location, topography, natural resources, commonalities, or economic similarities.

The proposed rules incorporate by reference the 2021 edition of the IECC with Michigan amendments, deletions, and additions published by the International Code Council (ICC). All surrounding Great Lakes states follow the International Energy Conservation Code, however, Michigan’s rules look to be more stringent and follow newer codes than similar states.

A. If the rules exceed standards in those states, please explain why and specify the costs and benefits arising out of the deviation.

The IECC is a nationally recognized model code used through the United States as a minimum standard. The Michigan rules do exceed the standards of any of the other Great Lake States, because the surrounding Great Lakes states still follow the 2007, 2010 and 2013 IECC. There are costs of deviation from other Great Lakes States because the State of Michigan is using the newest Energy Code, which accounts for new technologies in energy use and conservation. Once the other Great Lakes States adopt the newest Energy Code, or newer than what they currently use, those States will fall into line with what Michigan is currently adopting. The State of Michigan will be at the forefront of the most up to date Energy Code. Regardless of which Energy Code other States use, structure owners within the State of Michigan only use the Energy Code when building a new structure or renovating an existing structure. The costs the structure owner will realize is predicated upon the size of the structure. Therefore, the smaller the size of the new build, or renovated structure, the less it will cost that owner.

3. Identify any laws, rules, and other legal requirements that may duplicate, overlap, or conflict with the proposed rules.

There are no federal, state, or local laws, rules or other legal requirements that may duplicate, overlap, or conflict with the proposed rules.

A. Explain how the rules have been coordinated, to the extent practicable, with other federal, state, and local laws applicable to the same activity or subject matter. This section should include a discussion of the efforts undertaken by the agency to avoid or minimize duplication.

There are no federal, state, or local laws, rules or other legal requirements that may duplicate with the proposed rules.

4. If MCL 24.232(8) applies and the proposed rules are more stringent than the applicable federally mandated standard, provide a statement of specific facts that establish the clear and convincing need to adopt the more stringent rules.

MCL 24.232(8) does not apply to this ruleset because there are no applicable federally mandated standards.

5. If MCL 24.232(9) applies and the proposed rules are more stringent than the applicable federal standard, provide either the Michigan statute that specifically authorizes the more stringent rules OR a statement of the specific facts that establish the clear and convincing need to adopt the more stringent rules.

MCL 24.232(9) does not apply because there is no applicable federal standard that regulates the Energy Code.

Purpose and Objectives of the Rule(s)

6. Identify the behavior and frequency of behavior that the proposed rules are designed to alter.

MCL 125.1504(5) of the Stille-DeRossett- Hale Single State Construction Code Act requires the department to add, amend and rescind rules to update the IECC code not less than once every 3 years to coincide with the national code change cycle.

A. Estimate the change in the frequency of the targeted behavior expected from the proposed rules.

The proposed rules will adopt the 2021 edition of the IECC with amendments, deletions, and additions deemed necessary for use in Michigan.

B. Describe the difference between current behavior/practice and desired behavior/practice.

To comply with the requirements of the Stille-DeRossett- Hale Single State Construction Code Act the proposed rules will adopt the 2021 edition of the IECC with amendments, deletions and additions deemed necessary for use in Michigan.

C. What is the desired outcome?

The desired outcome is to bring the administrative application of the Energy Code rules in line with any current and upcoming rules, to eliminate unnecessary requirements in the code, and to have an easier interpretation and clarification of these rules.

7. Identify the harm resulting from the behavior that the proposed rules are designed to alter and the likelihood that the harm will occur in the absence of the rule.

MCL 125.1504(5) of the Stille-DeRossett- Hale Single State Construction Code Act requires the department to add, amend and rescind rules to update the IECC code not less than once every 3 years to coincide with the national code change cycle. Without implementation of the proposed rules businesses may not be able to take advantage of new methods, materials, or technologies.

A. What is the rationale for changing the rules instead of leaving them as currently written?

The Stille-DeRossett-Hale Single State Construction Code Act requires the department to update the codes not less than once every 3 years to coincide with the national code change cycle.

8. Describe how the proposed rules protect the health, safety, and welfare of Michigan citizens while promoting a regulatory environment in Michigan that is the least burdensome alternative for those required to comply.

R 408.31087 is administrative in nature and is amended to bring the administrative application of the IECC code rules in line with actual practices. Once the administrative rules are in line with the actual practices this will protect the health, safety, and welfare of Michigan citizens while promoting a regulatory environment in Michigan that is the least burdensome alternative for those required to comply.

9. Describe any rules in the affected rule set that are obsolete or unnecessary and can be rescinded.

The following rules are unnecessary because they are outdated and will be rescinded: R 408.31087a, R 408.31087b, R 408.31088, R 408.31090, R 408.31091, R 408.31092a, R 408.31094, R 408.31095, R 408.31096, R 408.31097, R 408.31098, R 408.31098a, and R 408.31098b.

Fiscal Impact on the Agency

Fiscal impact is an increase or decrease in expenditures from the current level of expenditures, i.e. hiring additional staff, higher contract costs, programming costs, changes in reimbursements rates, etc. over and above what is currently expended for that function. It does not include more intangible costs for benefits, such as opportunity costs, the value of time saved or lost, etc., unless those issues result in a measurable impact on expenditures.

10. Please provide the fiscal impact on the agency (an estimate of the cost of rule imposition or potential savings for the agency promulgating the rule).

There is no additional fiscal impact to the agency beyond the current operational costs.

11. Describe whether or not an agency appropriation has been made or a funding source provided for any expenditures associated with the proposed rules.

The proposed rules will not result in additional fiscal impact on the agency. Thus, there is no need for an additional appropriation or funding source as a result of the changes in the rules.

12. Describe how the proposed rules are necessary and suitable to accomplish their purpose, in relationship to the burden(s) the rules place on individuals. Burdens may include fiscal or administrative burdens, or duplicative acts.

R 408.31087 is administrative in nature and is amended to bring the administrative application of the IECC code in line with actual practices, as well as compliance with the Stille- DeRossett-Hale Single State Construction Code Act requirements. Although there is no administrative burden on the individual, there will be an increase in cost due to inflationary expenses for material costs in new build structures or renovations.

A. Despite the identified burden(s), identify how the requirements in the rules are still needed and reasonable compared to the burdens.

The amendments will clarify code requirements which will make compliance less burdensome. The individual may realize a net savings in energy costs pursuant to these requirements.

Impact on Other State or Local Governmental Units

13. Estimate any increase or decrease in revenues to other state or local governmental units (i.e. cities, counties, school districts) as a result of the rule. Estimate the cost increases or reductions for other state or local governmental units (i.e. cities, counties, school districts) as a result of the rule. Include the cost of equipment, supplies, labor, and increased administrative costs in both the initial imposition of the rule and any ongoing monitoring.

There is no anticipated increase or decrease in revenues to other state or local governmental units as a result of the proposed rules. Although state and local governmental units will incur upfront, higher costs, these expenses will be offset by the long-term financial savings as a result of this rule set. This bureau has no way of knowing what the additional specific expenses will be, as each individual structure will be unique to the needs of the governmental unit.

14. Discuss any program, service, duty, or responsibility imposed upon any city, county, town, village, or school district by the rules.

R 408.31087 is administrative in nature and is amended to bring the administrative application of the IECC code in line with the actual practices. It is anticipated that a local government unit would incur added responsibility due to the proposed rules. If a local unit of government has received the ability to administer and enforce the code under PA230 they would be responsible for learning, understanding, and applying the new code accurately.

A. Describe any actions that governmental units must take to be in compliance with the rules. This section should include items such as record keeping and reporting requirements or changing operational practices.

The proposed rules would require additional or new responsibilities on behalf of governmental units to be in continued compliance with the rules. They would be responsible for learning, understanding, and applying the new code accurately, which would require training of all applicable staff.

15. Describe whether or not an appropriation to state or local governmental units has been made or a funding source provided for any additional expenditures associated with the proposed rules.

There is no appropriation to state or local governmental units required.

Rural Impact

16. In general, what impact will the rules have on rural areas?

The proposed rules affect the state of Michigan as a whole. There is no specific rural impact, rules are applicable to both urban and rural new build structures alike. Pursuant to the Stille- DeRossett-Hale Single State Construction Code Act, there continues to be an agricultural exemption to the applicable construction codes. Therefore, there is no specific rule impact as these rules are applicable to urban and rural new building structures alike.

A. Describe the types of public or private interests in rural areas that will be affected by the rules.

Pursuant to the Stille- DeRossett-Hale Single State Construction Code Act, there is an agricultural exemption to the applicability of the construction codes. For those reasons, it is unlikely that the proposed rules will have any impact on public or private interests in rural areas. This is because the aforementioned act exempts the requirements to obtain a permit and inspection.

Environmental Impact

17. Do the proposed rules have any impact on the environment? If yes, please explain.

This is unknown. The agency does not have the scientific knowledge to determine what may or may not impact the environment.

Small Business Impact Statement

18. Describe whether and how the agency considered exempting small businesses from the proposed rules.

Because the Stille-DeRossett-Hale Single State Construction Code Act does not allow for exemption of small businesses from the Michigan Energy Code, the agency has no authority to exempt small businesses from the proposed rules.

19. If small businesses are not exempt, describe (a) the manner in which the agency reduced the economic impact of the proposed rules on small businesses, including a detailed recitation of the efforts of the agency to comply with the mandate to reduce the disproportionate impact of the rules upon small businesses as described below (in accordance with MCL 24.240(1)(a-d)), or (b) the reasons such a reduction was not lawful or feasible.

The agency was obligated to follow the Stille-DeRossett-Hale Single State Construction Code Act, which is applicable to scenario "(b) the reason such a reduction was not lawful or feasible" as the act did not provide for such an exemption within the aforementioned act.

A. Identify and estimate the number of small businesses affected by the proposed rules and the probable effect on small businesses.

According to the most current federal data available, Michigan has 765,487 small businesses. These businesses will be affected by this rule set. Only when a small business builds a new structure and renovations would they be affected by the proposed rules.

B. Describe how the agency established differing compliance or reporting requirements or timetables for small businesses under the rules after projecting the required reporting, record-keeping, and other administrative costs.

There is no additional reporting, record keeping, or other administrative costs associated with the implementation of the proposed rules.

C. Describe how the agency consolidated or simplified the compliance and reporting requirements for small businesses and identify the skills necessary to comply with the reporting requirements.

A small business that plans to construct a new build structure will not encounter reporting requirements.

D. Describe how the agency established performance standards to replace design or operation standards required by the proposed rules.

R 408.31087 adopts by reference the 2021 IECC code which is a nationally recognized model code. For that reason, the agency need not establish performance standards as the design and operation standards are established through the 2021 IECC code.

20. Identify any disproportionate impact the proposed rules may have on small businesses because of their size or geographic location.

The impact of these proposed rules will be directly correlated to the size of the new build structure, or renovation, a small business chooses to design. The larger the square footage of the new build structure or renovation, the higher the material costs and other associate expenses will incur. Any small business already established in a preexisting structure or moves into a preexisting structures will realize no impact by these proposed rules.

21. Identify the nature of any report and the estimated cost of its preparation by small businesses required to comply with the proposed rules.

The agency has not received any reports regarding the estimated costs to small businesses. There are no anticipated reports or increased costs to small businesses that are required to comply with the proposed rules.

22. Analyze the costs of compliance for all small businesses affected by the proposed rules, including costs of equipment, supplies, labor, and increased administrative costs.

The agency is unable to estimate compliance costs due to many variables which are at the discretion of a small business. In particular, the size of the new build structure, or its renovation, will dictate the ultimate expenses to the small business. Additionally, inflationary costs and specific material selections, will factor into the expenses for the small business.

23. Identify the nature and estimated cost of any legal, consulting, or accounting services that small businesses would incur in complying with the proposed rules.

The agency is unable to estimate legal, consulting or accounting costs due to many variables which are at the discretion of a small business. In particular, the size of the new build structure, or its renovation, will dictate the ultimate expenses to the small business. Additionally, inflationary costs and specific material selections, will factor into the expenses for the small business.

24. Estimate the ability of small businesses to absorb the costs without suffering economic harm and without adversely affecting competition in the marketplace.

The agency is unable to estimate what if any, economic harm may result due to the many variables which are at the discretion of a small business. In particular, the size of the new build structure, or its renovation, will dictate the ultimate expenses to the small business. Additionally, inflationary costs and specific material selections, will factor into the expenses for the small business.

25. Estimate the cost, if any, to the agency of administering or enforcing a rule that exempts or sets lesser standards for compliance by small businesses.

The proposed rules do not exempt or set lesser standards for compliance by small businesses. There is no additional cost to the agency beyond the current operational cost.

26. Identify the impact on the public interest of exempting or setting lesser standards of compliance for small businesses.

There is no public interest at play as it relates to exempting standards of compliance for small businesses.

27. Describe whether and how the agency has involved small businesses in the development of the proposed rules.

The bureau involved small businesses through the Code/ Rule Change Proposal Form as well as at the in person Public Advisory Meeting, the in person Public Hearing, along with having the ability to submit written documents to the bureau.

A. If small businesses were involved in the development of the rules, please identify the business(es).

The agency received proposed rules from the plumbing trade, electrical trade, mechanical contractors, building inspectors, residential builders, energy rating companies, and small home and residential builders.

Cost-Benefit Analysis of Rules (independent of statutory impact)

28. Estimate the actual statewide compliance costs of the rule amendments on businesses or groups.

The agency is unable to estimate compliance costs due to many variables which are at the discretion of a small business. In particular, the size of the new build structure, or its renovation, will dictate the ultimate expenses to the small business. Additionally, inflationary costs and specific material selections, will factor into the expenses for the small business. Groups will not be impacted with the rule amendments.

A. Identify the businesses or groups who will be directly affected by, bear the cost of, or directly benefit from the proposed rules.

The businesses and groups who will be directly affected by our proposed rules are those entities who either build a new structure or renovate an existing structure to work in or renovate an existing structure. Also, contractors will be affected by these proposed rules because they will be hired to construct to the new energy requirements. The businesses or groups who will directly benefit from the proposed rules will be the individuals producing the energy products and commercial and residential contractors because they will be able to profit through the hired work to be performed based upon the new energy code requirements. Additionally, structure owners will realize an energy costs savings, long-term, as these standards are implemented through new build or renovations. The individuals who will build a new structure or renovate an existing structure will bear the cost of the new standards.

B. What additional costs will be imposed on businesses and other groups as a result of these proposed rules (i.e. new equipment, supplies, labor, accounting, or recordkeeping)? Please identify the types and number of businesses and groups. Be sure to quantify how each entity will be affected.

The agency is unable to estimate costs due to many variables which are at the discretion of a business. In particular, the size of the new build structure, or its renovation, will dictate the ultimate expenses to the business. Additionally, inflationary costs and specific material selections, will factor into the expenses for the business. Groups will not be impacted with the rule amendments.

29. Estimate the actual statewide compliance costs of the proposed rules on individuals (regulated individuals or the public). Include the costs of education, training, application fees, examination fees, license fees, new equipment, supplies, labor, accounting, or recordkeeping.

In regard to the regulation of individuals, the agency is unable to determine what compliance costs they may incur. If a building official takes an energy code continuing education course from the agency, it will cost the regulated individual zero dollars. On the other hand, for profit companies could offer the same energy code continuing education course for a fee. If the regulated individual, chooses to take the for-profit code continuing course, the agency would not know what that compliance cost would be to the regulated individual. The agency leaves it to the discretion of the regulated individual to choose how they obtain their training. As for the public, the agency is unable to estimate costs due to many variables which are at the discretion of an individual. In particular, the size of the new build structure, or its renovation, will dictate the ultimate expenses to the individual. Additionally, inflationary costs and specific material selections, will factor into the expenses for the individual.

A. How many and what category of individuals will be affected by the rules?

It is anticipated that roughly 100,000 plus skilled trades licensees and other regulated individuals (including architects and engineers) will benefit from these proposed rules, but only when new build structures or renovations are contracted for.

B. What qualitative and quantitative impact do the proposed changes in rules have on these individuals?

The quantitative impact will be unknown as the agency is unable to estimate costs due to many variables which are at the discretion of the individual. In particular, the size of the new build structure, or its renovation, will dictate the ultimate expenses to the individual. Additionally, inflationary costs and specific material selections, will factor into the expenses for the individual. The qualitative impact to the individual will result in a cost savings in the long-term.

30. Quantify any cost reductions to businesses, individuals, groups of individuals, or governmental units as a result of the proposed rules.

The cost reductions will depend upon if the individual, business, group of individuals, or governmental units build a new structure or renovate an existing structure where they are located. If the aforementioned groups stay within their existing building, and never make changes to said building, they will neither incur costs nor realize savings based on this new set of rules.

31. Estimate the primary and direct benefits and any secondary or indirect benefits of the proposed rules. Please provide both quantitative and qualitative information, as well as your assumptions.

The primary and direct benefits of our proposed rules include things such as long-term costs savings, a reduction in the carbon footprint and other energy savings to the owners of new build structures and renovations. The secondary or indirect benefits of the proposed rules are the skilled trade professions who will benefit from the contracted work that will result from an updated energy code.

32. Explain how the proposed rules will impact business growth and job creation (or elimination) in Michigan.

The proposed rules will benefit the skilled trades profession as well as the energy related industry due to the new requirements which are established in this rule set.

33. Identify any individuals or businesses who will be disproportionately affected by the rules as a result of their industrial sector, segment of the public, business size, or geographic location.

There may be some individuals or businesses which may not build a new structure or renovate an existing structure because they will not wish to implement the new energy code standards. They may determine the existing structure in which they are located satisfies their immediate needs. This may result in higher energy costs for certain individuals and businesses who decide not to build a new structure or renovate an existing structure.

34. Identify the sources the agency relied upon in compiling the regulatory impact statement, including the methodology utilized in determining the existence and extent of the impact of the proposed rules and a cost-benefit analysis of the proposed rules.

The bureau consulted with the following trade boards; Construction Code Commission, the Plumbing Board, the Electrical Administrative Board, the Mechanical Contractor Board, the Residential Builders & Maintenance and Alteration Contractors Board as well as reviewed comments from the Code/Rule Proposal Form to compile the initial draft.

Next the bureau held a 3-day public advisory meeting where all stakeholders were invited to discuss with the agency any and all aspects, concerns, and goals as it relates to the final work product of these rules. Bureau staff considered all comments received during the drafting process including determining the existence and extent of the impact of the proposed rules and the cost benefit analysis of these proposed rules. Examples of stakeholders who helped contribute to this regulatory impact statement include but were not limited to; The Michigan Home Builders Association, Consumer Energy & DTE, Municipalities (specifically the City of Grand Rapids), building officials (inspectors), ASHREA, Architects and Engineers, Masonry Institute and energy home raters.

A. How were estimates made, and what were your assumptions? Include internal and external sources, published reports, information provided by associations or organizations, etc., that demonstrate a need for the proposed rules.

The bureau relied on the commission and stakeholders when determining the existence and extent of the impact of the proposed rules.

Alternative to Regulation

35. Identify any reasonable alternatives to the proposed rules that would achieve the same or similar goals.

No reasonable alternatives to the proposed rules have been identified that would achieve the same or similar goals.

A. Please include any statutory amendments that may be necessary to achieve such alternatives.

Although the agency does not believe any statutory amendments are necessary to the Stille-DeRossett-Hale Single State Construction Code Act, individuals who believe the energy code updates cause additional expenses to be incurred, may wish to lobby the legislature to extend the energy code adoption to greater than every three years.

36. Discuss the feasibility of establishing a regulatory program similar to that proposed in the rules that would operate through private market-based mechanisms. Please include a discussion of private market-based systems utilized by other states.

The bureau is unaware of similar programs or private market-based systems in other states.

37. Discuss all significant alternatives the agency considered during rule development and why they were not incorporated into the rules. This section should include ideas considered both during internal discussions and discussions with stakeholders, affected parties, or advisory groups.

The most significant alternative, which was presented to the agency and not adopted, was the proposition to require all new structures or renovations be exclusively electric in nature. This would mean no use of propane or natural gas. This would result in extraordinarily expensive construction beyond the current normal practice. It also eliminates possible cheaper modes to energy. At best it creates a monopoly, at worst this alternative would grind new construction to a halt. As of May 16, 2022, the Midcontinent Independent System Operator is preparing for a projected short fall in energy capacity for June, July and August 2022.

Additional Information

38. As required by MCL 24.245b(1)(c), please describe any instructions regarding the method of complying with the rules, if applicable.

There are no instructions regarding the method of complying with the rules.

phius ISAAC ELWECAVG
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Mr. Keith Lambert

Director, Bureau of Construction Codes

Michigan Department of Licensing and Regulatory Affairs

611 W Ottawa St.

Lansing, MI 48933

July 5th, 2022

Re: Michigan's 2021 Energy Conservation Code Adoption

Dear Director Lambert,

Phius (Passive House Institute US) is a non-profit 501(c)(3) organization committed to making high-performance passive building the mainstream market standard. Phius trains and certifies professionals, maintains the Phius climate-specific passive building standard, certifies and quality assures passive buildings, and conducts research to advance high-performance building. Buildings constructed to the Phius standard provide superior indoor air quality, resilience during power outages, and an extremely quiet, comfortable indoor environment. Project teams are increasingly adopting passive building principles and the Phius standard for single-family, multifamily, and commercial buildings to achieve Net Zero buildings, resulting in over 7,000 units certified, and totaling over 7.4 million square feet across North America. Project teams are increasingly adopting passive building principles and the Phius standard for single-family, multifamily, and commercial buildings to achieve Net Zero buildings, resulting in over 7,000 units certified, and totaling over 7.4 million square feet across North America.

Phius appreciates the opportunity to provide comments suggesting amendments to the proposed adoption of the 2021 International Energy Conservation Code (IECC). Phius congratulates the Michigan Department of Licensing and Regulatory Affairs (LARA) for proposing to adopt the 2021 IECC virtually unamended as the 2021 IECC is a significant improvement from the previous edition and will provide the state with a roadmap to cost-effective energy savings. However, Phius believes that LARA can include two amendments that would upgrade the energy code. These include:

1. **Amend the wall insulation prescriptive value in Table 402.1.3 from R20+5 tor R20+7**
2. **Add an alternative compliance path to residential and low-rise multi-family projects certified by Phius.**

1.Suggested Amendments:

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A. Amend the wall insulation prescriptive value in Table 402.1.3 from R20+5 tor R20+7.

Proposed Amended Language:

Table R402.1.3 INSULATION MINIMUM R-VALUES AND FENESTRATION REQUIREMENTS BY COMPONENT (Changes are underlined. Please see strike out and addition in bold in WOOD FRAME WALL R-VALUE COLUMN IN CLIMATE ZONES 5,6 & 7)

CLIMATE ZONE	FENESTRATION U-FACTOR	SKYLIGHT U-FACTOR	GLAZED FENESTRATON SHGC	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE	FLOOR R-VALUE
5 and Marine 4	0.30	0.55	0.40	60	*20+~~5ci~~ **7ci** or13+10ci or 0+15*	13/17	30
6	0.30	0.55	NR	60	*20+~~5ci~~ **7ci** or13+10ci or 0+15*	15/20	30
7 and 8	0.30	0.55	NR	60	*20+~~5ci~~ **7ci** or13+10ci or 0+15*	19/21	38

Rationale:

In the Residential Chapter of the 2021 International Energy Conservation Code, the wall insulation requirement in Table R402.1.3 (for both Climate Zone 5, &7) includes the option to use R20 +5 ci. R 20 + 5ci is an insulation assembly that specifies R-20 for cavity insulation along with R-5 for exterior continuous insulation. Unfortunately, this type of insulation assembly may pose moisture problems in Michigan's climate zone. According to the paper by the Building Science Corporation, BSD-163: Controlling Cold-Weather Condensation Using Insulation by John Straube[1], the exterior insulation R-value should be, at a minimum, roughly 35% of the cavity insulation. In the case of R20 + 5, the exterior insulation is 0.25 (5/20). There is insufficient exterior insulation to protect against cold-weather condensation in the walls.

To avoid the problem detailed above, the proposal is to amend the prescriptive R20 + 5ci requirement to R20 + 7ci. The additional exterior insulation would generate substantial benefits to homeowners in

[1] https://www.buildingscience.com/documents/digests/bsd-controlling-cold-weather-condensation-using-insulation

both additional energy savings and protection against cold-weather condensation and potential moisture-related problems.

Adding additional exterior insulation will slightly raise the cost. The difference between 1" of exterior insulation (R-5) and 1.5" (R-7.5) is about $7 per board (which is equivalent to 32 square feet). For a typical home, with roughly 1,800 square feet of wall area, the additional cost is about $400 per home. This cost must be weighed against both the additional energy savings as well as the saved cost from not having moisture problems. The costs due to moisture problems alone in walls would swamp any additional cost.

B. Add an alternative compliance path to residential and low-rise multifamily projects certified by Phius.

Proposed Amended Language:

R401.2 Application
Residential buildings shall comply with Section R401.2.~~5~~**6** and either Sections R401.2.1, R401.2.2, R401.2.3, ~~or~~ R401.2.4 **or R401.2.5.**

R401.2.5 Phius Alternative Compliance Option
The Phius Alternative Compliance Option requires compliance with Section R409
R401.2.~~5~~**6** Additional Energy Efficiency

Sections R409 Phius Alternative Compliance Option

R409.1. Scope. This section establishes criteria for compliance via the Phius 2021 standard.

R409.2 Projects shall comply with PHIUS 2021 Passive Building Standard, including its United States Department of Energy (USDOE) Energy Star and Zero Energy Ready Home co-requisites, and performance calculations by Phius-approved software.
R409.2.1 PHIUS documentation. Prior to the issuance of a building permit, the following items must be provided to the code official:

1. **A list of compliance features.**
2. **A PHIUS precertification letter.**

Prior to the issuance of a certificate of occupancy, the following item must be provided to the code official:

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1. A Phius 2021 (or later) project certificate.

Rationale:

Including Phius as an alternative compliance path, provides an option in the energy code for homes that are significantly more energy efficient than those meeting the 2021 IECC without adding any administrative cost to the process. This amendment will simplify the path for those homebuilders/homebuyers who would like to a home that is more energy efficiency than a similar home built to the 2021 IECC.

In addition, because Phius requires a robust 3rd party review and construction inspection process, people will be assured of a high-quality energy efficient home that will allow code officials to focus on enforcing other sections of the energy code.

Description of Phius Standard

All buildings built to the Phius standard foreground five principles:

- Using continuous insulation throughout the building envelope to minimize or eliminate thermal bridging.
- Building a well-detailed and extremely airtight building envelope, preventing infiltration of outside air and loss of conditioned air while increasing envelope durability and longevity.
- Using high-performance windows (double or triple-paned windows depending on climate and building type) and doors - solar gain is managed to exploit the sun's energy for heating purposes in the heating season and to minimize overheating during the cooling season.
- Using balanced heat- and moisture-recovery ventilation to significantly enhance indoor air quality.
- Minimizing the space conditioning system because of lower space conditioning loads.

The Phius standard incorporates all these principles. Moreover, to receive certification, all residential buildings must also meet the criteria laid out in these pre-requisite programs:

- US Environmental Protection Agency (EPA) ENERGY STAR Program
- EPA Indoor airPLUS program
- EPA WaterSense Program
- US Department of Energy (DOE) Zero Energy Ready Home program
- ASHRAE 62.2 ventilation requirements

All buildings seeking Phius certification go through a two-part process: design review, construction review and on-site verification:

PART 1:

First, Phius certification staff reviews construction drawings, product specifications, and modeling to ensure that the building energy use is below the stringent values specified in the standard. In addition to reviewing energy performance, building envelope components and details are evaluated for moisture and condensation performance. After all issues are identified and resolved, the building design is design certified.

PART 2:

After design certification, actual construction is reviewed on-site by a Phius-trained Rater/Verifier who ensures that the building is constructed to the pre-certified plans and that it meets the criteria of the programs listed above. If changes to the design occur, the modeling is updated, and the new energy use of the building must still meet the Phius standards for certification. This process ensures both quality construction and deep energy efficiency.

Phius Homes, Multi-Family Buildings and Commercial Building Provide Deep Energy Savings.

The Phius CORE standard, as noted above, is designed to maximize cost effective energy efficiency resulting in buildings that use significantly less overall energy. At the 2022 BuildBoston conference, the Massachusetts Department of Energy Resources presented the results of an analysis of the energy use of multi-family buildings. DOER found that Phius buildings had an Energy Use Intensity 60% below the code level energy use. Similar data from the Philadelphia benchmarking data analysis shows energy savings of around 50%.[2]

Currently, there are 8 Phius projects across Michigan. On average, these projects have a predicted Energy Use Intensity between 10 and 15 kBTU/sq. ft-yr. This is less than a 1/3 the energy use of homes meeting the strict Energy Star standard which are themselves more efficient than homes simply meeting the current energy code. For a comparison between a home meeting the Phius standard and a home meeting the 2021 IECC, please see Appendix A.

Phius buildings provides benefits beyond energy savings including: resilience and reduction in energy burden.

Resilience:

Phius construction principles align with an increase in resilience. Phius buildings emphasize the reduction of air flow into and out of buildings, the elimination of thermal bridges across the building envelope including the use of continuous insulation. This approach helps maintain the indoor temperature of a building which is particular important in a climate subject to extreme temperatures.

Energy Burden:

[2] Apigian, Michele et al. ***At the Finish Line: How Two Affordable passive Projects Crossed the Hardest Hurdles***; BuildingEnergy Boston, February 28, 2022

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According to the report, "Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low Income and Underserved Communities by the American Council for an Energy Efficient Economy, low-income residents of Detroit face among the highest energy burdens in the country. The energy burden for the median household in Michigan is 2.3%. This is almost half of the energy burden facing the median low-income household in the city which lands at 5.1% (the energy burden for the median African American family and Latino family is 4.1% and 3.1%, respectively). [3] High efficiency housing meeting the Phius standard, offering far lower energy costs over their lifetime (and drastically reduced emissions), are thus a strong opportunity to reduce the energy burden for Minnesota's low-income residents.

Phius Alternative Compliance Path Has been Implemented in Several Jurisdictions

The Phius alternate compliance path has already been implemented successfully in several state and municipal energy codes including Massachusetts, New York, Illinois, Washington, Chicago, and Denver. As it is an alternate compliance path administered by a third party, it would not add costs to either homebuyers or municipalities administering the code. However, it would function as a strong incentive towards the construction of very energy efficient homes.

Thank you for the opportunity to comment on these critical issues. Phius congratulates LARA for proposing to adopt the 2021 IECC, which will result in significant energy savings and higher quality homes and commercial buildings across Michigan. Phius also feels that by incorporating the suggested amendments, LARA will strengthen the proposal and position itself to continue to adopt strong energy codes in the future.

Sincerely,

Isaac Elnecave
Policy Specialist
Phius

[3] Drehobi and Ross, **"Lifting the Higher Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low Income and Underserved Communities,"** Appendix B. April 2016
https://www.aceee.org/sites/default/files/publications/researchreports/u1602.pdf

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APPENDIX A: Comparison Between a Home Meeting the Phius Standard (Prescriptive Path) and a Home Meeting the Prescriptive Requirements of the 2021 IECC (Table 402.1.3).

	2021 IECC	Phius
Ceiling Insulation (CZ 5)	R-60	R-70
Ceiling Insulation (CZ-6)	R-60	R-76
Basement Wall Insulation (CZ 5)	R-15 ci or R-19 or R-13 + 5 ci	R-20
Basement Wall Insulation (CZ 5)	R-15 ci or R-19 or R-13 + 5 ci	R-25
Window U-Factor (CZ 5)	0.30	0.17
Window U-Factor (CZ 6)	0.30	
Window Solar Heat Gain Coefficient (CZ 5)	0.40	NR
Window Solar Heat Gain Coefficient (CZ 6)	NR	NR
Wall Insulation (CZ 5)	R-30 or R-20+5 or R-13+10 or R-0+ 20	R-39
Wall Insulation (CZ 6)	R-30 or R20+5 or R-13+10 or R-0+ 20	R-45
Slab Insulation and depth (CZ 5)	R-10; 4 ft	R-20; 4ft
Slab Insulation and depth (CZ 6)	R-10; 4 ft	R-25; 4 ft
Air Sealing	3 ACH50	0.6 ACH 50
Energy Rating Index (ERI) (Climate Zone 5)	55	35
Energy Rating Index (ERI) (Climate Zone 6)	54	35

This chart details requirements for homes in Metro Detroit- Climate Zone 5 and Northern Michigan – Climate Zone 6. As Phius is a climate-dependent standard, the R-values are higher in Climate Zone 6.

Director Orlene Hawks
Michigan Department of Licensing and Regulatory Affairs
611 W. Ottawa Street
Lansing, MI 48933

Dear Director Hawks,

I am the owner of Grantham Building and Remodeling, LLC in Petoskey, Michigan. We have been in business since 1993 and specialize in the renovation of historic homes in northern Michigan. I am writing to convey my comments and questions relative to the promulgation of Part 10 Michigan Uniform Energy Code rules, 2021-48 LR by your department.

Historically, our state has used model codes developed by the International Code Council (ICC) as the starting point for code changes, usually amending such codes to align with our state law and other unique aspects of our state's geography. For this and other reasons noted below, I oppose the unilateral implementation of the 2021 International Energy Conservation Code (IECC). This action fails to recognize our festering Michigan housing crisis. The cost of building a typical Michigan home has doubled in price over the past five years and, as such, fewer and fewer Michiganders can afford to buy or rent a home. This proposed rule set, if applied to residential construction, would mandate several thousand dollars in additional costs for new homes. Perhaps an unintended consequence, our typical renovation customer would also be impacted by these proposed rules since the scope of work (under 2015 MRC) requires a substantial remodel to be brought into full compliance of the residential code and its references. A recent study showed that for every thousand-dollar increase in home construction costs, nearly 5,300 households in our state are priced out of being able to afford it. If this rule set is adopted without amendment and is applied to residential housing, fewer people will be able to afford more energy efficient homes. This is no understatement.

In terms of following state law, the issuance of the Regulatory Impact Statement and Cost Benefit Analysis (RIS) for the Part 10 Michigan Uniform Energy Code rules, 2021-48 LR raised significant questions for me and others in our industry. In addition to many other questions that may have been raised, I believe these three questions need to be answered by your department before further action is taken:

1. Prior to the issuance of the regulatory impact statement, what studies, analyses and/or reports have been done or relied on by the State to confirm that the proposed rules are "cost-effective" within the meaning of MCL 125.1502a?
2. Do the proposed rules apply to bed and breakfast dwellings and ADUs?
3. Will the proposed rules apply to homes to undergo renovation regardless of the extent of scope?

Thank you for the consideration of my comments and questions.

Jeff Grantham

Jeff Grantham
CGR CAPS CGP GMB

PIMA
POLYISOCYANURATE INSULATION MANUFACTURERS ASSOCIATION

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Sent via Electronic Mail

June 27, 2022

Amanda Johnson, Rules Analyst
Michigan Department of Licensing and Regulatory Affairs
Bureau of Construction Code, Administrative Services Division
611 W. Ottawa Street
Lansing, Michigan 48933
LARA-BCC-Rules@michigan.gov

Re: Support for Adoption of the 2021 International Energy Conservation Code
(Pending Rule Sets 2021-48LR and 2021-49LR)

Dear Ms. Johnson,

The Polyisocyanurate Insulation Manufacturers Association (PIMA) is writing in support of the proposed rules for adopting the 2021 IECC for residential and commercial buildings. Keeping the State's energy code updated to the current version of the IECC is an important and cost-effective policy for addressing the negative economic and environmental consequences of energy waste in buildings – a sector that is responsible for 40% of total U.S. energy use. Importantly, Michigan will benefit from the removal of several previously adopted amendments that in the past weakened the code's stringency and undermined the achievement of State's climate goals. Also, adopting the 2021 IECC will help Michigan achieve a range of benefits, including:

- Reduced air pollution;
- Consumer and business cost savings;
- Increased flexibility and reliability of our energy system and grid;
- Improved resiliency;
- Reduced peak energy demand; and
- Improved energy productivity and a stronger economy.

Staying current with the model energy code ensures that Michigan will benefit from the regular improvements in construction practices and building technology. This is especially true for alterations performed on commercial buildings and ensures that the energy code will drive energy efficiency improvements in existing buildings when components are replaced or when buildings are otherwise altered.

Moving from Michigan's current energy code, which is based on the 2015 IECC (and the ASHRAE Standard 90.1-2013), to the 2021 IECC will save Michigan residents money and increase employment. Also, this change is clearly cost effective. For commercial buildings, this change has a simple payback that is immediate, and for residential buildings purchased with a mortgage, there would be a positive net savings within 5 years. Over 30 years, about 15,000 jobs would result from these stronger energy codes.[1]

Most of the country views stronger building energy codes as an effective policy that benefits the environment and the economy. Like Michigan, your neighbors -- Illinois and Ohio -- are in the midst of adopting the 2021 IECC for both residential and commercial buildings and Wisconsin is close to adopting this code for commercial buildings and will soon start its review for residential buildings.

Buildings are responsible for 74% of total electricity consumption in the United States. Twenty-seven percent of Michigan's electricity is still generated by burning coal, a product that comes entirely from out-of-state.[2] As a result, weak building energy codes send money out of Michigan to purchase coal. Adopting the 2021 IECC will improve building energy efficiency, reduce energy use and waste, and result in investments that benefit the state and local economies.

About PIMA

PIMA is the trade association for North American manufacturers of rigid polyiso foam insulation – a product that is used in most low-slope commercial roofs as well as in commercial and residential walls. Polyiso insulation products and the raw materials used to manufacture polyiso are produced in over 50 manufacturing facilities across North America. The insulation industry overall employs over 12,000 workers in the Michigan.

Thank you for the opportunity to submit these comments. Please contact me should additional information be necessary (jkoscher@pima.org; (703) 224-2289).

Sincerely,

Justin Koscher
President

[1] U.S. Department of Energy, see "State Energy Code Fact Sheet-Michigan", https://www.energycodes.gov/sites/default/files/2021-07/EED_1365_BROCH_StateEnergyCodes_states_MICHIGAN.pdf

[2] U.S. Energy Information Administration, https://www.eia.gov/beta/states/states/mi/analysis

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Director Orlene Hawks
Michigan Department of Licensing and Regulatory Affairs
611 W. Ottawa Street
Lansing, MI 48933

Date: 06/28/2022

Dear Director Hawks,

I am the CEO of Hiawatha Log Homes based in Michigan's Upper Peninsula. Hiawatha Log Homes employs a local workforce and purchases supplies and materials from surrounding Michigan businesses and has been designing and manufacturing custom log homes and structures made of freshly harvested wood from sustainably managed forests in Michigan's Upper Peninsula for over 38 years. I am writing to comment, express concern and seek clarification relative to the promulgation of Part 10 Michigan Uniform Energy Code rules, 2021-48 LR by your department.

I oppose the implementation of the 2021 International Energy Conversation Code (IECC) without amendment in our state. Doing so will fail to recognize long-standing precedent and state law. Historically, our state has used model codes as the starting point for code changes, making changes as appropriate for our climate and other laws intended to balance new energy efficiency requirements and affordability. This action, as proposed, would also appear to conflict with our state government goals of increasing the supply of more attainable/affordable homes. The cost of building a typical Michigan home has doubled in price over the past five years. The proposed energy code changes your department is considering, if applied to residential construction, would add several thousand dollars in additional costs. Your department has received data, in prior public meetings, showing that for every thousand-dollar increase in home construction costs, nearly 5,300 households in our state are priced out of being able to afford it. If this rule set is adopted without amendment and is applied to residential housing, fewer people will be able to afford more energy efficient homes.

In terms of following state law, the issuance of the Regulatory Impact Statement and Cost Benefit Analysis (RIS) for the Part 10 Michigan Uniform Energy Code rules, 2021-48 LR raised significant questions for me, as a log home manufacturer. I believe two key questions need to be answered by your department before further action is taken:

1. Do the proposed rules apply to residential buildings using log walls? Walls built with logs and CLT (cross laminated timber) incorporate high thermal mass qualities into the building envelop and provide exceptional energy efficiencies.
2. Will buildings built to the 2022 ICC-400 Standard on the Design and Construction of Log Structures be considered in compliance with the proposed rules?

Thank you for the consideration of my comments and questions.

Sincerely,

Joe Esbrook

Joe Esbrook
Chief Executive Officer & Operating Partner

Hiawatha Log Homes
www.hiawatha.com

build smarter. live better.
SableHomes
Healthier Homes
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Director Orlene Hawks
Michigan Department of Licensing and Regulatory Affairs
611 W. Ottawa Street
Lansing, MI 48933

Dear Director Hawks,

I am the President of Sable Homes, a residential construction company in West Michigan, building single family homes since 1996. I am writing to convey my comments, concerns and questions relative to the promulgation of Part 10 Michigan Uniform Energy Code rules, 2021-48 LR by your department.

I oppose the unilateral implementation of the 2021 International Energy Conversation Code (IECC) in our state. Historically, our state has used model codes developed by the International Code Council (ICC) as the starting point for code changes, typically amending such codes to align with our state law and other unique aspects of our great state. Your department seems intent on disregarding this history and precedent. Further, this action fails to recognize the Michigan housing affordability/ attainability housing crisis. The cost of building a typical Michigan home has doubled in price over the past five years. The proposed energy code changes your department is considering, if applied to residential construction, would add several thousand dollars in additional costs for new homes. We know that for every thousand-dollar increase in home construction costs, nearly 5,300 households in our state are priced out of being able to afford it. If this rule set is adopted without amendment and is applied to residential housing, fewer people will be able to afford more energy efficient homes.

In terms of following state law, the issuance of the Regulatory Impact Statement and Cost Benefit Analysis (RIS) for the Part 10 Michigan Uniform Energy Code rules, 2021-48 LR raised significant questions for me and others in our industry. I believe these three questions need to be answered by your department before further action is taken:

1. Which amendment cycle provision of MCL 125.1504 are the proposed rules being promulgated under – subsection (5) or subsection (6)?
2. What is the amendment cycle for the residential section 10 of the MEC? Is it every three years or not less frequently than once every 6 years or more frequently than once every 3 years? and
3. What is the amendment cycle for Chapter 11 of the Michigan Residential Code? Is it every three years or is it not less frequently than once every 6 years or more frequently than once every 3 years?

Thank you for the consideration of my comments and questions.

Sincerely,

John Bitely

John Bitely
President

Mr. Keith Lambert
Director, Bureau of Construction Codes
Michigan Department of Licensing and Regulatory Affairs
611 W Ottawa St.
Lansing, MI 48933

June 30, 2022
Re: Michigan's Energy Code Adoption

Dear Director Lambert,

RMI (formerly Rocky Mountain Institute) and the New Buildings Institute (NBI) respectfully submit the following comments to the Department of Licensing and Regulatory Affairs (LARA) on the amendments for the Michigan Energy Code. RMI is an independent, non-partisan, non-profit organization whose mission includes researching the business models, policies, technologies, and financing mechanisms necessary to advance an equitable clean energy transition. New Buildings Institute (NBI) works collaboratively with industry market players—governments, utilities, energy efficiency advocates and building professionals—to promote advanced design practices, innovative technologies, public policies, and programs that improve energy efficiency at the highest levels and decarbonize the built environment.

Michigan will benefit from 2021 IECC with commercial energy monitoring, efficiency packages, EV-readiness, and all-electric amendments.

We applaud LARA for including 2021 IECC in this initial draft for Michigan's updated energy codes. 2021 IECC is necessary for Michigan to have modern, affordable new construction. With the adoption of 2021 IECC, we encourage LARA to consider the following amendments:

1. Include the energy monitoring section – Section C405.12 to C405.12.5, which requires energy monitoring for buildings over 25,000 square feet in the commercial code. This amendment is a key tool for tracking energy use and helping commercial buildings reduce consumption.
2. Require EV-readiness in both the residential and commercial code. EV-readiness in new homes will enable customer choice for their transportation without homeowners having to pay up to x3-4 more later to retrofit compared to building to EV-readiness standards.[1]
3. Include an amendment to the proposed code to require at least three options be selected from the list of Additional Efficiency Package Options. This amendment can generate high energy savings at low costs while providing builders with flexibility in complying with a high efficiency code.

In addition, we strongly recommend that Michigan adopt an all-electric new construction amendment in climate zones 5 and 6 alongside an electric-ready amendment in climate zone 7. All-electric new construction benefits Michiganders because it has lower upfront costs than a mixed fuel home built to current code and can help keep utility bills stable amid rising, volatile gas prices. At minimum, an electric-ready amendment enables customers to use best in class technology. Failure to at least require electric readiness will create logistical and economic hurdles for customers to gain access to modern, efficient, healthy appliances like heat pumps in the future.

[1] https://newbuildings.org/wp-content/uploads/2022/04/BuildingDecarbCostStudy.pdf

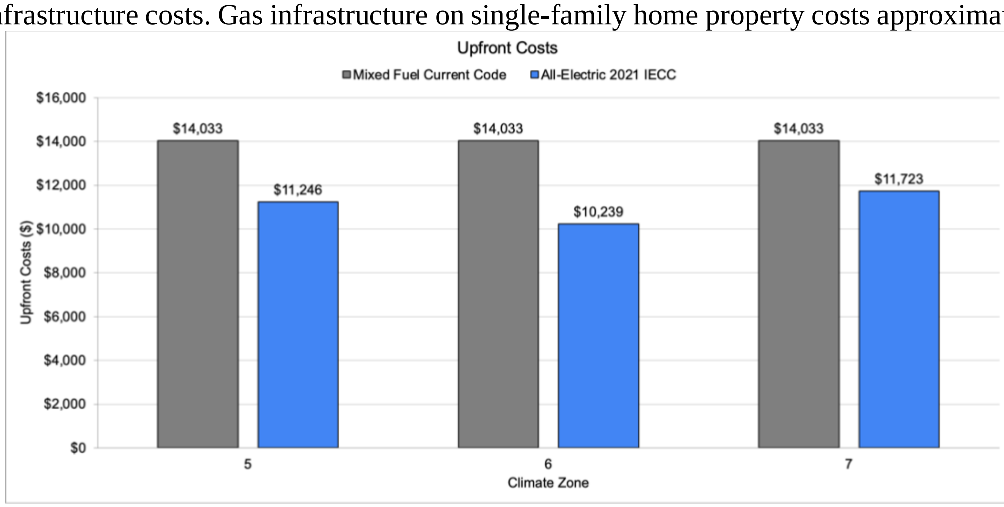
All-electric and electric-ready codes are being passed across the U.S.

States and cities across the United States are passing all-electric or electric-ready codes giving new home residents access to innovative, efficient appliance technologies, like heat pumps and induction stoves. Over 60 jurisdictions across 11 States have already adopted policies that require or encourage building electrification.[2] The most recent example in the codes space is Washington state which just passed an all-electric heating mandate in commercial and multifamily buildings.[3] Colorado passed a law requiring cities and counties to update their building codes to be electric-ready.[4] Alongside states, local jurisdictions, like New York City, have passed all-electric new construction bills as well.[5] Michigan is positioned to join these states and cities as a leader in the new construction sector.

All-electric codes will economically benefit Michiganders

All-electric construction codes in Michigan can reduce costs for residents. RMI and NBI submitted analysis to LARA, in service of the Stille-Derossett-Hale Single State Construction Code Act[6], examining the upfront and life cycle costs of all-electric new construction codes in Michigan.[7] Our study concludes that for single-family new construction:

1. **All-electric new construction could reduce upfront costs by over $2,000 compared to a mixed fuel home built to current code**. All-electric homes reduce upfront costs because they avoid gas infrastructure costs. Gas infrastructure on single-family home property costs approximately $6000.



2. **All-electric new construction is cost neutral over seven years in climate zones 5 and 6.** The costs a homeowner would pay in the first seven years (including utility bills, mortgage bills, property taxes, and a down payment on upfront costs) are comparative to a single-family mixed

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[2] https://www.buildingdecarb.org/zeb-ordinances.html

[3] https://grist.org/buildings/washington-state-requires-electric-heat-pumps-buildings/

[4] https://www.bouldercounty.org/news/boulder-county-commissioners-welcome-landmark-energy-codes-legislation/

[5] https://www.urbangreencouncil.org/content/projects/local-law-154-nycs-all-electric-new-buildings-law#:~:text=With%20Local%20Law%20154%2C%20New,and%20making%20occupants%20more%20comfortable

[6] http://www.legislature.mi.gov/(S(ervayhjjbvqjiirehphhi4dk))/mileg.aspx?page=getobject&objectname=mcl-act-230-of-1972&queryid=40215&highlight=

[7] https://www.michigan.gov/lara/-/media/Project/Websites/lara/bcc-media/Rules-Info/Part-10-Michigan-Energy-Code/Compiled-2021-Energy-Codes-Advisory-Meeting-Comments-322.pdf?rev=9fe80d902fc547ac864918012652d6a2&hash=061E4101D96506D30961ABDF9D2A84F9

fuel home built to current code. This finding indicates new construction can benefit from the health and comfort benefits of an all-electric home without a cost premium.[8]

3. **Cost-effectiveness for all-electric new construction is improving**. Our analysis was conservative using rates from November 2021 and minimum code compliant appliances. The cost-effectiveness of all-electric codes will improve with high performance cold climate heat pumps, heat pump friendly electric rates, and utility incentives, which this analysis did not include to comply with the Stille-Derossett-Hale Single State Construction Code Act.

In conclusion, our study finds that all-electric code amendments in Michigan can reduce upfront costs making housing more accessible to more Michiganders. This benefit comes with comparable lifecycle costs and will be subject to less gas price volatility.

All-electric new construction avoids rising, volatile gas prices

Michigan utilities are warning that rising natural gas prices will lead to utility bill hikes for residents.[9] These claims are backed by new research from the Michigan Public Service Commission which expects natural gas prices to increase by 89% between 2021 and 2022, a stark difference from the 6.4% increase of electric rates between May 2021 and May 2022.[10] Low-income Michiganders, who already spend 15% of their income on energy, can't afford to be subject to volatile, rising gas prices.[11] Since heat pumps are highly efficient and leverage steadier electricity prices, all-electric new construction can help keep bills low and steady for Michigan residents. All-electric codes, which leverage the benefits of electric appliances, can help ease these concerns and mitigate future price hikes from the continued build out of gas infrastructure. As Michigan adds more renewable resources to the grid, these prices will become even more stable because it is not dependent on imported fuels.

All-electric or electric-ready codes benefit Michigan's economy and enable customer choice.

Considering the results of this analysis, we recommend that all-electric 2021 IECC be adopted in Climate Zones 5 and 6. In Climate Zone 7, we recommend that Michigan adopt electric-ready 2021 IECC. All-electric codes will provide residents with low-upfront costs while reducing indoor air pollution emissions and keeping utility bills stable. At minimum, electric-ready will enable Michigan to leverage modern technologies when homeowners are ready to do so. Electric-ready construction provides residents with the most consumer choice when it is time to decide how they will heat their home, water, and food. It provides them with the option to use heat pumps and induction stoves which are innovative technologies that can keep Michigan warm and comfortable on the coldest days and keep utility bills and mortgage payments low and steady.

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[8] https://rmi.org/wp-content/uploads/2022/02/all_electric_buildings_healthy_factsheet.pdf
[9] https://www.thedailyreporter.com/story/news/2021/09/10/michigan-gas-utility-rates-increase-2022/8264271002/
[10] https://www.michigan.gov/mpsc/-/media/Project/Websites/mpsc/regulatory/reports/energy-appraisal/2022_Summer_Energy_Appraisal.pdf
[11] https://www.elevatenp.org/wp-content/uploads/Energy-Burden-in-MI.pdf

Home Innovation Response to ICF Comments Regarding 2021 IECC Residential Cost Effectiveness Analysis

This is a response by Home Innovation Research Labs to an ICF report that contradicted the analysis in Home Innovation's *2021 IECC Residential Cost Effectiveness Analysis*.[1] Home Innovation stands by our analysis as comprehensive and accurate.

The 2021 IECC includes several changes that impact both energy savings and construction costs for residential construction. The objective of the Home Innovation analysis was to quantify the incremental construction cost and energy use cost savings associated with constructing a house compliant with the 2021 IECC, relative to a 2018 IECC baseline, and to evaluate the cost-effectiveness of the code changes.

In response, ICF prepared a report and accompanying comparison document with concerns and issues. Per ICF, "This analysis is intended to 'check the math' of the NAHB report using current cost data and widely accepted cost effectiveness metrics." Throughout their report, ICF makes comparisons to a 2021 IECC analysis by Pacific Northwest National Laboratory (PNNL).[2]

Home Innovation reviewed the ICF report and accompanying comparison document. The different results between the Home Innovation and ICF reports are primarily due to different incremental construction costs, and the decision around which of these costs should be included to evaluate cost-effectiveness. To calculate cost-effectiveness, ICF used Home Innovation's energy use costs, but developed their own construction costs. ICF used bare material costs that are generally much lower than Home Innovation's and, in some cases, eliminated costs altogether. ICF used the same base labor costs as Home Innovation, but did not accurately account for subcontractor overhead. Finally, ICF did not properly apply builder gross margin to total subcontractor costs. As a result, ICF underestimated the total construction costs to consumer. Home Innovation stands by our construction costs as comprehensive, robust, and accurate.

ICF's issues with Home Innovation's report fall within three broad categories: **(1)** Metric used to evaluate cost-effectiveness; **(2)** Methodology and construction data (e.g., housing starts, foundation type) used for the analysis; and **(3)** Construction costs. Our response to the issues raised by ICF in these categories is provided below.

(1) Metric used to evaluate cost-effectiveness

- ICF criticized Home Innovation for using only the Simple Payback metric to evaluate cost-effectiveness. Home Innovation uses Simple Payback because that is what builders use. Life Cycle Cost (LCC), Simple Payback, and Net Present Value/Cash Flow methods can all be used to calculate cost-effectiveness, but real-world builders do not use LCC to make design and construction decisions because the housing finance system does not support that methodology. ICF used LCC and Simple Payback; PNNL used all three. The value of any metric depends mostly on accurate construction costing and energy modeling. The metrics are inter-related – results from one metric will generally not be improved simply by selecting another.

[1] Home Innovation 2021 IECC analysis: https://www.homeinnovation.com/trends_and_reports/featured_reports/2021_iecc_residential_cost_effectiveness_analysis

[2] PNNL analysis: https://www.energycodes.gov/sites/default/files/2021-07/2021IECC_CostEffectiveness_Final_Residential.pdf

(2) Methodology and construction data used for the analysis

- ICF criticized Home Innovation's methodology and source of data, the Builder Practices Survey (BPS), used to determine weighted national average results and reference new home characteristics compared to Census data used by DOE/PNNL. Reported data on home starts and characteristics are actually very similar between these two sources – and ultimately, so are the results for energy savings. BPS data rely on an annual survey with about 1,500 home builders participating each year, reporting on the characteristics of the 40,000+ homes they constructed. There are some differences in reporting conventions between the two sources that can account for the minor variations between BPS and Census data. For example, the BPS reports single-family detached housing starts and characteristics, while Census single-family housing includes detached and attached units. The table below shows housing starts distribution across Climate Zones used in the PNNL and Home Innovation analyses.

Construction Data Comparison: Housing Starts						
	CZ 2	**CZ 3**	**CZ 4**	**CZ 5**	**CZ 6**	**CZ 7**
Home Innovation	28%	28%	21%	17%	5%	1%
PNNL, adjusted by combining CZ1&2 and CZ7&8	*26.73%*	*29.04%*	*19.49%*	*19.51%*	*4.68%*	*0.55%*

  There were some differences in the construction data used for analysis – Home Innovation evaluated single-family detached housing only, while PNNL evaluated single-family and low-rise multifamily buildings. For primary heating fuel, Home Innovation evaluated natural gas or electric, depending on the predominant fuel by location; PNNL evaluated natural gas, electric, and fuel oil (however, fuel oil represents a relatively small 3.8% of housing starts and therefore does not have a significant impact on the weighted results). Despite these differences, and the different data sources and geographic locations selected for energy modeling, the results for national average energy cost savings are similar: 8.66% for PNNL; 9.7% for Home Innovation. ICF acknowledged the results are comparable, but pointed to two outliers where the results were farther apart (Climate Zones 3 and 7). Home Innovation discussed those in 2021 with PNNL and determined the differences do not significantly affect our national average results. Regardless, even though ICF disputes the validity of Home Innovation's energy results, they still *used* Home Innovation's energy results (i.e., our methodology and weighting) in their analysis.

- ICF criticized Home Innovation for including the costs of code changes in the cost-effectiveness analysis when these code changes were not included in the energy modeling analysis. However, these costs are real and must be included to accurately account for the cost of compliance associated with the 2021 IECC. This is an important distinction that can significantly affect any cost-effectiveness analysis. For this study it is likely the second most important difference, after construction costs, between the different results. We included all construction costs in our analysis because all the code changes are required for compliance with the 2021 IECC (as applicable, meaning not all changes are applicable in all Climate Zones), and it was necessary in order to evaluate the overall cost-effectiveness of the 2021 IECC relative to the 2018 IECC. Where we investigated the cost-effectiveness of individual code changes (e.g., ceiling insulation, wall insulation, slab insulation, window U-factor, additional efficiency package options), we only used the construction cost associated with the individual change, so this issue did not impact those results.

  We determined construction costs for a total of 20 code changes. Ten of those code changes have a direct impact on energy efficiency and can be reasonably quantified through energy modeling – e.g., more ceiling insulation, more efficient windows, etc. PNNL and Home Innovation selected the same 10 code changes for energy modeling. The other code changes that were not included in the energy modeling are changes with either no energy savings (i.e., administrative, such as a providing a certificate) or energy savings that can't reasonably be accounted for (e.g., insulation baffles at the attic access hatch; air-sealed electrical outlet boxes; exterior lighting controls). Some of these changes represent minor costs while others are more significant, but all are *real costs* and should be included in the analysis to accurately account for the total construction cost of compliance associated with the 2021 IECC changes.

- ICF wrongly stated that Home Innovation made a misleading comparison of cost effectiveness by comparing the 2021 efficiency package options to a 2021 baseline in Table 21, and that we should have compared those to a 2018 baseline. Table 11 in our report shows exactly what ICF is recommending – we compare the 2021 with and without package options to the 2018 baseline. Table 21 was included specifically to evaluate individual code changes. Further, we evaluated four of the five 2021 IECC additional efficiency package options; PNNL limited their investigation to one (water heating).

Table 11. Simple Payback relative to 2018 Baseline Reference House, years

Configuration	National Average	CZ 2 Phoenix	CZ 3 Memphis	CZ 4 Baltimore	CZ 5 Chicago	CZ 6 Helena	CZ 7 Duluth
2021 without additional efficiency package options	48	43	31	62	61	47	78
2021 with HVAC option	38	47	39	39	32	19	24
2021 with Water Heater option	32	20	20	54	54	42	79
2021 with Ventilation option	67	90	49	75	68	50	63
2021 with Duct option, slab house	38	38	36	46	39	23	26
2021 with Duct option, vented crawlspace house			30	46			

(3) Construction Costs

- ICF used lower material costs and, in some cases, eliminated costs that we believe are required. Home Innovation stands by our costs as robust, comprehensive, and accurate, understanding that builders may adjust the final costs as they see fit. We build *real* prices, for *real* builders. We conduct many cost studies, and our results are commonly vetted by both large- and small-volume builders and their purchasing staff. We developed our estimated costs based on current 2021 RSMeans Residential Data, the most recognized industry standard for costing, using national average costs for labor and construction materials; mechanical equipment costs were sourced from national distributor websites. We show our assumptions and individual component costs in Appendix A of our reports, so we are very transparent. Home Innovation also relies on internet pricing, as needed, but, without due diligence and construction experience, price information found on the internet may not consistently capture accurate costs. An internet price, for example, may represent a sale price that is only available for a limited time or not available nationwide. Likewise, internet pricing information may not be complete – e.g., a linear foot price for piping may not include fittings and hangers; a shingle price may not include delivery onto the roof or account for normal waste; blown ceiling insulation sold by the bag requires a cost calculation to convert cubic feet to square foot of ceiling for a given R-value; and so on. RSMeans incorporates this type of comprehensive calculation, which minimizes the potential for errors; an estimate that does not use RSMeans must be transparent about the calculation.

- ICF applies the builder gross margin as if it were a mark-up – this is an error and underestimates the final cost to consumers. ICF provides an example for a $200 cost to builder with $247 cost to consumer and states that this represents a 24% gross margin, but that calculation is incorrect. This example actually represents a 19.0% gross margin ($47/$247) and an approximate 24% mark-up ($47/$200). This is not trivial. For a contractor, misunderstanding this concept can be the difference between being a viable business and going out of business.

- Home Innovation applied a builder gross margin of 19% (not 24% as ICF claimed). ICF used a gross margin of 17.5% (applied as a mark-up) based on a 15-year average (no source provided for this data), which further underestimates the current cost to consumers. Home Innovation used the most recent data available: 19% was the industry average gross profit margin for 2017 as reported by the NAHB 2019 Builder's Cost of Doing Business Study.[3] Since then, a 2020 NAHB study reports an average 20.4% builder gross margin for 2019.[4]

- ICF stated, "the excessively high profit margin of 24% was applied twice, once reflecting the subcontractor's profit and again to reflect the builder's profit." ICF is not correct in this depiction. Home Innovation assumed that all construction was conducted by subcontractors and applied a gross margin of 19% (not 24%) only once. ICF conflates builder gross margin and subcontractor overhead – those are separate and distinct items and, again, not a trivial matter to misinterpret them.

- ICF improperly accounts for subcontractor's overhead for labor – where labor is a factor, the real cost to builders and consumers will be higher. ICF marked-up materials and labor by about 10% but did not apply an overhead burden to labor first. RSMeans provides the "Total Cost Including Overhead and Profit" for the installing contractor (designated by RSMeans as "Total Incl O&P" and designated by Home Innovation in our tables as "w/O&P"). This represents the total cost charged by the subcontractor to the builder. Note that this figure is normally not calculated by the estimator. Per RSMeans, this figure is the sum of the bare material cost plus 10% for profit, the bare equipment cost plus 10% for profit, and the base labor cost plus overhead and 10% for profit. The base labor cost includes fringe benefits, such as vacation pay and employer-paid healthcare. Overhead includes direct overhead, such as workers' compensation insurance, federal and state unemployment costs, and social security taxes, and fixed overhead (RSMeans uses 18.5% for 2021). RSMeans determines the national average cost for overhead and applies this as a mark-up to the base labor cost. This mark-up varies by trade, but the average for skilled workers (comprising 35 trades) is 54.5% (i.e., multiply the base labor cost by 1.545), before the 10% profit for the subcontractor. These figures represent national averages as reported by RSMeans 2021 Residential Cost Data. Note that RSMeans does not include costs for general conditions, contingencies, or sales tax on materials.

- ICF applied a factor of 79.3% to subcontractor mark-ups to reflect the average share of construction costs that are subcontracted. We consider this arbitrary and inconsistent with RSMeans. There is always overhead

[3] NAHB 2019 Study: https://eyeonhousing.org/2019/03/builders-profit-margins-continue-to-slowly-increase/?_ga=2.73913042.1310550892.1620653840-1896975365.1593698293

[4] NAHB 2020 Study: https://eyeonhousing.org/2020/02/cost-of-constructing-a-home-in-2019/

associated with labor and construction, and builder gross margin does not include overhead associated with total construction cost. Large builders typically subcontract all construction. Where builders have an in-house crew or division, these typically operate as an independent profit center and likely would charge the same as a subcontractor – they will still have direct labor overhead and overhead associated with construction. Further, smaller builders that likely subcontract less (e.g., do their own carpentry), generally have larger overhead as a percentage of sales (per RSMeans).

- ICF incorrectly states that, for 19 of the 153 houses modeled, Home Innovation reported "a significant error where the reported energy use and energy rates did not result in the documented energy costs." However, the energy costs that we reported were calculated by the energy modeling software BEopt hourly simulation software, developed by DOE. Calculating the results manually, as ICF apparently did, is more likely to introduce errors.

- ICF took issue with our costing of a few minor items (e.g., $114 administrative costs). A builder may choose to reduce or eliminate our estimated costs for these code changes, but doing so does not affect our analysis or results in any meaningful way.

CONCLUSION

Home Innovation stands by our results. We build *real* prices, for *real* builders. We base our estimated costs on current RSMeans Residential Data (2021 data for this report), using national average costs for labor and construction materials, and mechanical equipment costs sourced from distributor websites. We show our assumptions and individual component costs in Appendix A of our reports, so our analysis is transparent. Our cost studies and results are commonly vetted by builders, large and small, and their professional purchasing staffers. If a builder believes any assumptions we make or costs are wrong, rest assured, we hear about it. Anecdotally, we recently presented a similar study, and the feedback from major national builders was, "I don't think we could do it for that," meaning our estimates were conservative and might even be low. In another recent study, we evaluated the installed costs of wall cavity insulation and ceiling insulation and found that current RSMeans costs correlate well with market internet pricing. Actual costs will vary by builder and location, but our costs are likely low for many smaller builders with less purchasing power, and may even be low now for larger builders due to current market conditions. Also, note that our cost analysis does not account for the inflation that is throughout the economy and widespread within the building industry.

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July 1, 2022

Keith Lambert
Bureau of Construction Codes
Department of Licensing and Regulatory Affairs
Administrative Services Division
P.O. Box 30254
Lansing, MI 48909

Re: MEEA's comments in support of the adoption of the 2021 International Energy Conservation Code for residential and commercial buildings

Dear Mr. Lambert and the Bureau of Construction Codes,

Thank you for the opportunity to provide comments on current update to the Michigan Energy Code. The Midwest Energy Efficiency Alliance (MEEA) is a member-based non-profit organization promoting energy efficiency to optimize energy generation, reduce consumption, create jobs and decrease carbon emissions in all Midwest communities. We have submitted numerous comments on this process, and thus will be brief in this round.

MEEA recommends the adoption of the 2021 International Energy Conservation Code (IECC) without weakening amendments as the statewide minimum building energy code for residential and commercial buildings. Adopting the 2021 IECC without weakening amendments would establish a number of benefits for Michiganders and result in more efficient, resilient buildings, plus put the state on track to meet its established climate goals.

The proposed energy code released by LARA on June 16, 2022, appears to have a few amendments that weaken the 2021 IECC. In the residential energy code, R408.301066 and R408.31071 remain; these amendments have previously impacted the alternative performance path and systems sections in Michigan's energy code and will continue to reduce the efficiency and efficacy of the residential energy code. In addition, a referenced table is now numbered differently and could be problematic if not updated. The proposed commercial energy code removes monitoring requirements and some requirements for lighting alterations. If these sections remain in the upcoming code, Michiganders will not be able to realize the full benefits of the 2021 IECC.

The 2021 IECC has proven to be cost-effective and will save residents and business owners on their utility bills. According to reports from the US Department of Energy and the Pacific Northwest National Laboratory, "adopting the 2021 IECC in Michigan is expected to result in homes that are energy efficient, more affordable to own and operate, and *based on current industry standards* for health, comfort and resilience."[1] Additionally, moving to the commercial 2021 IECC will reduce statewide CO_2 emissions by 10.0 MMT (30 years cumulative), equivalent to the CO_2 emissions of 2,182,000 cars driven for one year, and stimulate the creation of high-

[1] https://www.energycodes.gov/sites/default/files/2021-07/MichiganResidentialCostEffectiveness_2021_0.pdf

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quality jobs across the state[2]. Only if adopted in full, with no amendments, will Michiganders realize these intended benefits.

Increasingly Michigan municipalities have expressed interest to MEEA for the ability to adopt advanced energy codes. One option the state of Michigan has would be to adopt the 2021 IECC Appendices so that municipalities are given the choice of more stringency in energy efficiency beyond the state energy code. MEEA recommends that the state of Michigan strongly consider giving municipalities this option and can provide technical expertise on stretch code adoption and implementation. Please let us know if you if you need more information on that option.

The adoption of the 2021 IECC is a cost-effective way to gradually increase the level of efficiency of residential and commercial buildings and remain a leader in the Midwest. We recommend the full unamended adoption of the 2021 IECC as a way to reduce long-term energy use and costs for residents and businesses, create healthier and more comfortable indoor environments, and increase the resiliency of the building stock so new residential dwellings and commercial buildings last for the next 75-100 years.

If you have any questions about this testimony, noted reports and references or general impact and analysis of building energy codes, please contact Alison Lindburg, Senior Building Policy Manager for MEEA at alindburg@mwalliance.org.

Sincerely,

Stacey Paradis

Stacey Paradis

Executive Director

[2] https://www.energycodes.gov/sites/default/files/2021-07/Cost-effectiveness_of_ASHRAE_Standard_90-1-2019-Michigan.pdf

7/2/2022

Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Administrative Services Division
Telephone (517) 582-5519
LARA-BCC-Rules@michigan.gov

My name is Roger Papineau. I live at 1901 Beulah Highway, PO Box 574, Beulah, MI 49617. I am writing today to give comments and questions on the proposed Part 10 and 10a Energy Code Rules.

1. If the proposed rules are promulgated, will residential provisions of the Michigan Energy Code (Part 10) and the Michigan Residential Code (Chapter 11) conflict?
2. If provisions of the Michigan Energy Code (Part 10) and Michigan Residential Code (Chapter 11) do conflict, will the Michigan Residential Code provisions take precedence over the Michigan Energy Code?
3. Do the proposed rules amend Chapter 11 (Energy Efficiency) of the 2015 Michigan Residential Code?

Retain and amend R 408.31060e.
Reason: Parts 10 &10a are unique to Michigan. It makes no sense to list over 3140 counties, boroughs, and parishes across the United Sates in a code book dedicated to Michigan.
Also, the current copy of ASHRAE 169-2013 puts Marquette in Zone 6A, not 7A. This change is required to maintain consistency across the various codes.
Additionally, Figure R301.1 is nearly impossible to read.

Code change proposal CE36-19 Part II revised the makeup of the climate zones.
IECC: FIGURE R301.1 (IRC N1101.7), TABLE R301.1 (IRC N1101.7), R301.3 (IRC N1101.7.2), TABLE R301.3(1) [IRC N1101.7.2(1)], TABLE R301.3(2) [IRC N1101.7.2(2)]
Proponent: David Collins, representing SEHPCAC (SEHPCAC@iccsafe.org); David Collins, representing The American Institute of Architects (dcollins@preview-group.com)

Reason:
Currently approximately 10% of the counties across the US have different climate zones under the IECC and ASHRAE 90.1, ASHRAE 90.2, and the IgCC. This proposal updates the climate zones to correspond with the release of ASHRAE Standard 169-2013, which is referenced in both the 2018 IgCC and ASHRAE 90.1 and ASHRAE 90.2 Approximately 10% of the counties in the United States have a change in Climate Zone designation due to this change. ICC has a licensing agreement with ASHRAE to include the climate zone map, definitions and tables for consistency with ASHRAE Standard 169-2013.
ANSI/ASHRAE Addendum a to ANSI/ASHRAE Standard 169-2013 shows Marquette County MI to be in Climate Zone 6A. See Figure A-1 and Table A-3.

Delete without substitution Section R404.2.
Reason: This section increases the cost of construction with no return on investment due to the requirement that all lamps be hi-efficacy.