

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

July 2021

Victor R Salcido
Yan Chen
YuLong Xie
Zachary T Taylor

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes **any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.** Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

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

Printed in the United States of America

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

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

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

July 2021

Victor R Salcido
Yan Chen
YuLong Xie
Zachary T Taylor

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

Pacific Northwest National Laboratory
Richland, Washington 99354

Highlights

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

Moving to the 2021 International Energy Conservation Code (IECC) is cost-effective for both single-family and low-rise multifamily residential buildings in Colorado. The 2021 IECC will provide statewide energy savings of 19.9% across all climate zones compared to the current state energy code. This equates to \$ 410 of annual utility bill savings for the average Colorado household. It will reduce statewide CO₂ emissions over 30 years by 18,070,000 metric tons, equivalent to the annual CO₂ emissions of 3,931,000 cars on the road (1 MMT CO₂ = 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 Colorado 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	\$7,133
Net annual consumer cash flow in year 1 of the 2021 IECC ²	\$193
Annual (first year) energy cost savings of the 2021 IECC (\$) ³	\$410
Annual (first year) energy cost savings of the 2021 IECC (%) ⁴	19.9%

¹ A weighted average is calculated across building configurations and climate zones.

² The annual cash flow is defined as the net difference between annual energy savings and annual cash outlays (mortgage payments, etc.), including all tax effects but excluding up-front costs (mortgage down payment, loan fees, etc.). First-year net cash flow is reported; subsequent years' cash flow will differ due to the effects of inflation and fuel price escalation, changing income tax effects as the mortgage interest payments decline, etc.

³ Annual energy savings is reported at time zero, before any inflation or price escalations are considered.

⁴ Annual energy savings is reported as a percentage of end uses regulated by the IECC (HVAC, water heating, and interior lighting).

Statewide Impact - Emissions

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, \$	4,455,000	1,558,000,000
CO ₂ emission reduction, Metric tons	37,060	18,070,000
CH ₄ emissions reductions, Metric tons	1.95	949
N ₂ O emissions reductions, Metric tons	0.269	131
NO _x emissions reductions, Metric tons	23.22	11,320
SO _x emissions reductions, Metric tons	7.91	3,859

Statewide Impact – Jobs Created

Statewide Impact	First Year	30 Years Cumulative
Jobs Created -- Reduction in Utility Bills	253	7192
Jobs Created -- Construction Related Activities	1033	29360

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 ₂ O	Nitrous Oxide
NO _x	Nitrogen Oxides
PNNL	Pacific Northwest National Laboratory
SO _x	Sulfur Oxides

Contents

1.0	Cost-Effectiveness Results for the 2021 IECC for Michigan	1
1.1	Life-Cycle Cost	1
1.2	Consumer Cash Flow	2
1.3	Simple Payback Period	3
2.0	Overview of the Cost-Effectiveness Analysis Methodology	5
2.1	Estimation of Energy Usage and Savings	5
2.2	Climate Zones	6
2.3	Fuel Prices	7
2.4	Financial and Economic Parameters	8
2.5	Aggregation Scheme	8
3.0	Incremental Construction Costs	10
4.0	Energy Cost Savings	12
5.0	Societal Benefits	14
5.1	Benefits of Energy Codes	14
5.2	Greenhouse Gas Emissions	14
5.3	Jobs Creation through Energy Efficiency	16
6.0	References	17

Figures

Figure 1.	National Climate Zones	7
-----------	------------------------------	---

Tables

Table 1.	Life-Cycle Cost Savings of the 2021 IECC compared to the 2015 IECC with amendments	2
Table 2.	Consumer Cash Flow from Compliance with the 2021 IECC Compared to the 2015 IECC with amendments	3
Table 3.	Simple Payback Period for the 2021 IECC Compared to the 2015 IECC with amendments	4
Table 4.	Fuel Prices used in the Analysis	7
Table 5.	Economic Parameters Used in the Analysis	8
Table 6.	Heating Equipment Shares	9
Table 7.	Foundation Type Shares	9
Table 8.	Construction Shares by Climate Zone	9
Table 9.	Total Single-Family Construction Cost Increase for the 2021 IECC Compared to the 2015 IECC with amendments (\$)	10

Table 10. Total Multifamily Construction Cost Increase for the 2021 IECC Compared to the 2015 IECC with amendments (\$) 11

Table 11. Annual (First Year) Energy Costs for the 2015 IECC with amendments 12

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

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

Table 14. Greenhouse Gas Emission Factors for Michigan by Fuel Type 15

Table 15. Societal Benefits of the 2021 IECC 15

Table 16. Jobs Created from the 2021 IECC 16

1.0 Cost-Effectiveness Results for the 2021 IECC for Colorado

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.gov¹.

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 2009 IECC

Climate Zone	Life-Cycle Cost Savings (\$)
4B	8,350
5B	7,079
6B	7,737
7	7,762
State Average	7,133

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 2009 IECC.

Table 2. Consumer Cash Flow from Compliance with the 2021 IECC Compared to the 2009 IECC

	Cost/Benefit	4B	5B	6B	7	State Average
A	Incremental down payment and other first costs	\$633	\$571	\$511	\$698	\$574
B	Annual energy savings (year one)	\$476	\$419	\$429	\$506	\$423
C	Annual mortgage increase	\$219	\$197	\$177	\$241	\$198
D	Net annual cost of mortgage interest deductions, mortgage insurance, and property taxes (year one)	\$35	\$31	\$28	\$38	\$31
E						
=	Net annual cash flow savings (year one)	\$223	\$191	\$225	\$227	\$193
[B-(C+D)]						
F						
=	Years to positive savings, including up-front cost impacts	3	3	3	3	3
[A/E]						

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 2009 IECC

Climate Zone	Payback Period (Years)
4B	10.6
5B	10.9
6B	9.5
7	11.0
State Average	10.9

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 2009 IECC. 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 (BECF 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 ft² 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 ft² 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 zone¹ in the state using DOE's *EnergyPlus*TM 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.

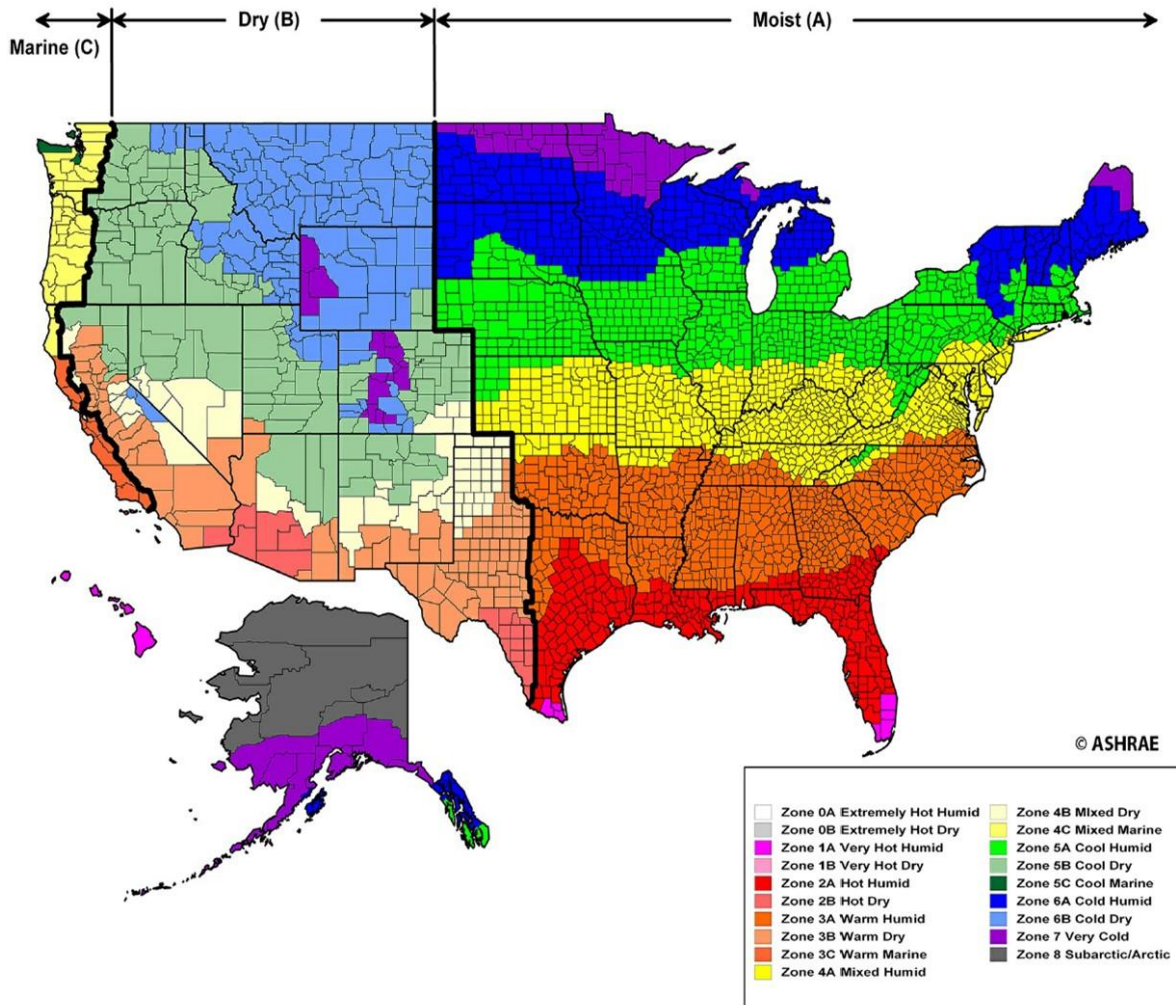


Figure 1. National Climate Zones

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)
0.125	0.584	2.519

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	4.55%
Property tax	0.6%

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 Colorado 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	80.7	80.7
Heat Pump	16.9	16.9
Electric Resistance	2.2	2.2
Oil	0.2	0.2

Table 7. Foundation Type Shares

Foundation Type	Slab-on-grade	Heated Basement	Unheated Basement	Crawlspace
Share of New Homes (percent)	30.4	26.1	8.7	34.8

Table 8. Construction Shares by Climate Zone

Climate Zone	Share of New Homes (percent)	
	Single-Family	Multifamily
4B	62.2	37.8
5B	62.2	37.8
6B	62.2	37.8
7	62.2	37.8

3.0 Incremental Construction Costs

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

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

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

The estimated costs of implementing the prescriptive provisions of the 2021 IECC over the 2009 IECC 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 2009 IECC 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, 0.9715, 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 2009 IECC (\$)

Single-family Prototype House				
Climate Zone	Crawlspace	Heated Basement	Slab	Unheated Basement
4B	\$6,362	\$6,362	\$6,861	\$6,362
5B	\$5,452	\$6,111	\$5,951	\$5,452
6B	\$5,122	\$5,122	\$5,122	\$5,122
7	\$6,579	\$6,579	\$6,579	\$6,579

Table 10. Total Multifamily Construction Cost Increase for the 2021 IECC Compared to the 2009 IECC (\$)¹

Multifamily Prototype Apartment/Condo				
Climate Zone	Crawlspace	Heated Basement	Slab	Unheated Basement
4B	\$2,254	\$2,254	\$2,328	\$2,254
5B	\$2,182	\$2,280	\$2,256	\$2,182
6B	\$2,062	\$2,062	\$2,062	\$2,062
7	\$3,519	\$3,519	\$3,519	\$3,519

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

2009 IECC

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 2009 IECC

Table 11. Annual (First Year) Energy Costs for the 2009 IECC

Climate Zone	2009 IECC						
	Heating	Cooling	Water Heating	Lighting	Fans	Vents	Total
4B	\$497	\$219	\$163	\$193	\$122	\$43	\$2,079
5B	\$507	\$168	\$170	\$193	\$136	\$43	\$2,060
6B	\$625	\$128	\$187	\$193	\$127	\$43	\$2,144
7	\$706	\$99	\$196	\$193	\$123	\$43	\$2,201
State Average	\$517	\$165	\$172	\$193	\$135	\$43	\$2,066

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

Climate Zone	2021 IECC						
	Heating	Cooling	Water Heating	Lighting	Fans	Vents	Total
4B	\$273	\$174	\$73	\$151	\$86	\$21	\$1,617
5B	\$314	\$145	\$77	\$151	\$105	\$21	\$1,652
6B	\$420	\$109	\$86	\$151	\$102	\$21	\$1,728
7	\$393	\$98	\$92	\$151	\$87	\$50	\$1,710
State Average	\$319	\$143	\$78	\$151	\$104	\$22	\$1,656

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 2009 IECC

Climate Zone	First Year Energy Cost Savings	First Year Energy Cost Savings (percent)
4B	\$462	22.2%
5B	\$407	19.8%
6B	\$417	19.4%
7	\$491	22.3%
State Average	\$410	19.9%

5.0 Societal Benefits

5.1 Benefits of Energy Codes

It is estimated that by 2060, the world will add 2.5 trillion square feet of buildings, an area equal to the current building stock. As a building's operation and environmental impact is largely determined by upfront decisions, energy codes present a unique opportunity to assure savings through efficient building design, technologies, and construction practices. Once a building is constructed, it is significantly more expensive to achieve higher efficiency levels through later modifications and retrofits. Energy codes ensure that a building's energy use is included as a fundamental part of the design and construction process; making this early investment in energy efficiency will pay dividends to residents of Colorado 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 (CH₄) and nitrous oxide (N₂O) 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 CO₂, NO_x, SO₂, CH₄ and N₂O (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 CO₂ 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 NO_x and SO₂ 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 NO_x and SO₂ in physical units but does not monetize these.

AVERT does not develop associated marginal emissions factors for CH₄ or N₂O. To provide estimates for the associated emission reductions for CH₄ and N₂O, 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 CH₄ or N₂O 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 Colorado by Fuel Type

GHG	Electricity lb/MWh	Natural Gas (lb/mmcf)	Fuel Oil (lb/1000 gal)
CO ₂	1,883	120,000	23,000
SO ₂	0.571	0.6	12
NO _x	1.041	96	19
N ₂ O	0.022	0.23	0.45
CH ₄	0.133	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 (CO₂, CH₄, and N₂O) emission reductions, in addition to NO_x and SO₂ reductions.

Table 15. Societal Benefits of the 2021 IECC

Statewide Impact	First Year	30 Years Cumulative
Energy cost savings, \$	4,455,000	1,558,000,000
CO ₂ emission reduction, Metric tons	37,060	18,070,000
CH ₄ emissions reductions, Metric tons	1.95	949
N ₂ O emissions reductions, Metric tons	0.269	131
NO _x emissions reductions, Metric tons	23.22	11,320
SO _x emissions reductions, Metric tons	7.91	3,859

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	253	7192
Jobs Created -- Construction Related Activities	1033	29360

6.0 References

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

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

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

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

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

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

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

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

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

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

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

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

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

- Faithful + Gould. 2012. *Residential Energy Efficiency Measures: Prototype Estimate and Cost Data*. Faithful+Gould for Pacific Northwest National Laboratory. Available at http://bc3.pnnl.gov/sites/default/files/Residential_Report.pdf
- ICC. 2014. *2015 International Energy Conservation Code*. International Code Council, Washington, DC. Available at <http://codes.iccsafe.org/app/book/toc/2015/InternationalCodes/2015%20IECC%20HTML/index.html>
- ICC. 2017. *2018 International Energy Conservation Code*. International Code Council, Washington, DC. Available at <https://shop.iccsafe.org/codes/2018-international-codes-and-references/2018-international-energy-conservation-code/2018-international-energy-conservation-coder.html>
- IWG – Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. 2016. *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. Available at https://www.epa.gov/sites/production/files/2016-12/documents/sc_tsd_august_2016.pdf
- IWG – Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. 2021. *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990*. Available at https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf
- Lucas R.G., Z.T. Taylor, V.V. Mendon, and S.G. Goel. 2012. *National Energy and Cost Savings for New Single- and Multifamily Homes: A Comparison of the 2006, 2009 and 2012 Editions of the IECC*. Pacific Northwest National Laboratory, Richland, Washington. Available at <https://www.energycodes.gov/sites/default/files/documents/NationalResidentialCostEffectiveness.pdf>
- Mendon V.V. and Z.T. Taylor. 2014. *Development of Residential Prototype Building Models and Analysis System for Large-Scale Energy Efficiency Studies Using EnergyPlus*. 2014 ASHRAE/IBPSA-USA Building Simulation Conference, Atlanta, GA.
- Mendon V.V., A. Selvacanabady, M. Zhao, and Z.T. Taylor. 2015. *National Cost-Effectiveness of the Residential Provisions of the 2015 IECC*. Pacific Northwest National Laboratory, Richland, Washington. Available at https://www.energycodes.gov/sites/default/files/documents/2015IECC_CE_Residential.pdf
- NREL. 2014. *National Residential Efficiency Measures Database*. National Renewable Energy Laboratory, Golden, Colorado. Available at <http://www.nrel.gov/ap/retrofits/>
- NAHB. 2009. *Builder Practices Reports*. National Association of Home Builders, Upper Marlboro, Maryland. Available at http://www.homeinnovation.com/trends_and_reports/data/new_construction
- RECS – Residential Energy Consumption Survey. 2013. *2009 RECS Survey Data*. U.S. Energy Information Administration. Washington D.C. Available at <https://www.eia.gov/consumption/residential/data/2009/>

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

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

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

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

Pacific Northwest National Laboratory

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

www.pnnl.gov