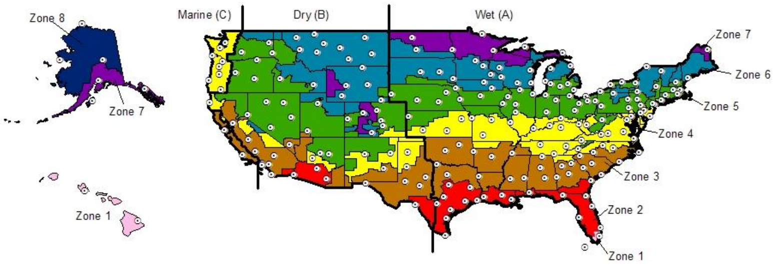
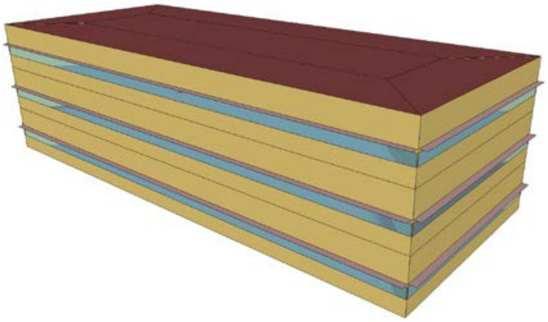
NIST Special Publication 1165

Benefits and Costs of Energy Standard Adoption in New Commercial Buildings: State-by-State Summaries

Joshua Kneifel

http://dx.doi.org/10.6028/NIST.SP.1165





BIRDS
Building Industry
Reporting and
Design *for*
Sustainability

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

NIST Special Publication 1165

Benefits and Costs of Energy Standard Adoption in New Commercial Buildings: State-by-State Summaries

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September 2013

U.S. Department of Commerce
Penny Pritzker, Acting Secretary

National Institute of Standards and Technology
Patrick D. Gallagher, Under Secretary of Commerce for Standards and Technology and Director

National Institute of Standards and Technology Special Publication 1165
Natl. Inst. Stand. Technol. Spec. Publ. 1165, 110 pages (September 2013)
CODEN: NSPUE2
http://dx.doi.org/10.6028/NIST.SP.1165

Abstract

Energy efficiency requirements in current commercial building energy codes vary across states. Energy standards that are currently adopted by states range from *ASHRAE 90.1-1999* to *ASHRAE 90.1-2007*. Some states do not have a code requirement for energy efficiency, leaving it up to the locality or jurisdiction to set their own requirements. The six National Institute of Standards and Technology (NIST) Special Publications (1147, 1148-1, 1148-2, 1148-3, and 1148-4) use the Building Industry Reporting and Design for Sustainability (BIRDS) database to analyze the impacts that the adoption of newer, more efficient commercial building energy codes would have on building energy use, operational energy costs, building life-cycle costs, and energy-related carbon emissions for each state by Census Region. This study summarizes the results from the series of documents for each of the 50 states into a two-page section.

Keywords

Building economics; economic analysis; life-cycle costing; life-cycle assessment; energy efficiency; commercial buildings

Preface

This study was conducted by the Applied Economics Office in the Engineering Laboratory at the National Institute of Standards and Technology (NIST). The study summarizes the energy consumption, life-cycle cost, and energy-related carbon emissions impacts from the adoption of new state energy codes based on more efficient building energy standards based on the BIRDS database for all 50 states. The intended audience is the National Institute of Standards and Technology, researchers in the commercial building sector, and any other government or private research group that is concerned with energy efficiency in commercial building designs.

Disclaimers

Certain trade names and company products are mentioned in the text in order to adequately specify the technical procedures and equipment used. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products are necessarily the best available for the purpose.

The policy of the National Institute of Standards and Technology is to use metric units in all of its published materials. Because this report is intended for the U.S. construction industry that uses U.S. customary units, it is more practical and less confusing to include U.S. customary units as well as metric units. Measurement values in this report are therefore stated in metric units first, followed by the corresponding values in U.S. customary units within parentheses.

Acknowledgements

The author wishes to thank all those who contributed ideas and suggestions for this report. They include Dr. David Butry and Dr. Robert Chapman of Engineering Laboratory's (EL's) Applied Economics Office, Mr. Matthew Boyd of EL's Energy and Environment Division, and Dr. Nicos S. Martys of EL's Materials and Structural Systems Division. A special thanks to Mr. Nicholas Long and the EnergyPlus Team for generating the initial energy simulations for this project. Thanks to Mr. Brian Presser for adapting the energy simulations to meet the study requirements and generating the final simulations used in the database. Thanks to Mr. Nathaniel Soares for developing the initial version of the BIRDS database, and to Ms. Priya Lavappa for enhancing the database for the current analysis.

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List of Acronyms

Acronym	**Definition**
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BIRDS	Building Industry Reporting and Design for Sustainability
CBECS	Commercial Buildings Energy Consumption Survey
CO2e	Carbon Dioxide Equivalent
EL	Engineering Laboaratory
LEC	Low Energy Case
NIST	National Institute of Standards and Technology
PV	Present Value
SP	Special Publication
TN	Technical Note

Executive Summary

Energy efficiency requirements in current commercial building energy codes vary across states. Current state energy code adoptions range from *American Society of Heating, Refrigerating and Air-Conditioning Engineers* (*ASHRAE) Standard 90.1-1999* to *ASHRAE 90.1-2007*. Some states do not have a code requirement for energy efficiency, leaving it up to the locality or jurisdiction to set its own requirement. There may be significant energy and cost savings to be realized by states if they were to adopt more energy efficient commercial building energy standards.

This report creates two-page summaries of the results from the series of National Institute of Standards and Technology (NIST) Special Publications (SP 1148-1, SP 1148-2, SP 1148-3, SP 1148-4)[1] that compare current state energy code performance to the performance of alternative building energy standards for each state by Census Region to determine whether these newer energy standards are cost-effective in reducing energy consumption and energy-related carbon emissions. The analysis includes a "Low Energy Case" (LEC) building design based on the energy efficiency requirements in *ASHRAE 189.1-2009,* which increases energy efficiency beyond the *ASHRAE 90.1-2007* design. These results are based on 13 680 whole-building energy simulations covering 11 building types in 228 cities across all states in the U.S. for a 10-year study period.

Results are analyzed in both percentage and absolute value terms. The percentage savings results allow for direct comparisons across energy standards, building types, study period length, climate zones, and cities within each state. Results are aggregated at the state level to estimate the magnitude of total energy use savings, energy cost savings, life-cycle cost savings and energy-related carbon emissions reductions that could be attained by adoption of a more energy efficient state energy code. Given the assumptions required in this analysis for building design and volume of new construction, the results should be considered as orders of magnitude impacts instead of precise estimates.

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[1] NIST SP 1148-1: Benefits and Costs of Energy Standard Adoption in New Commercial Buildings: Northeast Census Region
NIST SP 1148-2: Benefits and Costs of Energy Standard Adoption in New Commercial Buildings: Midwest Census Region
NIST SP 1148-3: Benefits and Costs of Energy Standard Adoption in New Commercial Buildings: South Census Region
NIST SP 1148-4: Benefits and Costs of Energy Standard Adoption in New Commercial Buildings: West Census Region

1 Introduction

Energy efficiency requirements in current commercial building energy codes vary across states. Current state energy code adoptions range from *American Society of Heating, Refrigerating and Air-Conditioning Engineers* (*ASHRAE) Standard 90.1-1999* to *ASHRAE 90.1-2007*. Some states do not have a code requirement for energy efficiency, leaving it up to the locality or jurisdiction to set its own requirement. There may be significant energy and cost savings to be realized by states if they were to adopt more energy efficient commercial building energy standards.

Kneifel (2010) and Kneifel (2011a) develop a framework to simultaneously analyze the impacts of improving energy efficiency on energy use, energy costs, life-cycle costs, and carbon emissions reduction through an integrated design context for new commercial buildings.[2] This framework was used to create the Building Industry Reporting and Design for Sustainability (BIRDS) database, the analysis capabilities of which were discussed in NIST Special Publication 1147. NIST SP 1148-1, 1148-2, 1148-3, and 1148-4 are a series of reports that analyze the results from the BIRDS database for all states in each of the four U.S. Census Regions. NIST SP 1161 summarizes the key results from NIST SP 1147 and the NIST SP 1148 series to highlight the implications of a nationwide adoption of new, more efficient state commercial building energy codes.

This report condenses the results based on the BIRDS database reported in the NIST SP 1148 series into a two-page synopsis for each state. The summary for each state reports the potential impacts on the state from adopting new state energy codes that increase the energy efficiency in new commercial and non-low-rise residential buildings across four metrics: energy use savings, energy cost savings, life-cycle cost savings, and energy-related carbon emissions reductions.

For this report, current state energy codes for commercial and non-low-rise residential buildings (residential buildings greater than three stories) are based on different editions of the *International Energy Conservation Code* or *ASHRAE Standard 90.1*, which have requirements that vary based on a building's characteristics and the climate zone of the building location as shown in Figure 1-1.[3] For this study, the prescriptive requirements of different *ASHRAE Standard 90.1*-equivalent designs are used to meet current state energy codes and to define the alternative building designs. States that have not yet adopted a state energy code are assumed to meet *ASHRAE 90.1-1999* building energy efficiency requirements because it is assumed to represent minimum energy-related industry practices. A "Low Energy Case" (LEC) design based on *ASHRAE 189.1-2009*, which goes beyond *ASHRAE 90.1-2007*, is included as an additional building design alternative.

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[2] Emissions are reported in metric tons of carbon dioxide equivalent or tCO_2e.

[3] Source: NIST SP 1161

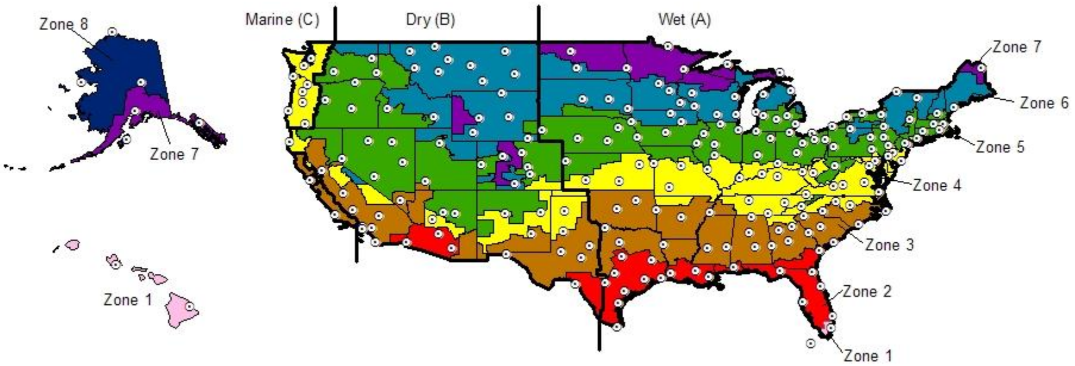

Figure 1-1 Cities and *ASHRAE* Climate Zones

The baseline for each state is compared to the higher energy efficiency building designs to determine the relative annual energy savings resulting from adopting the alternative standard edition as the state's energy code. For example, if a state's energy code has adopted *ASHRAE 90.1-2001* as its energy standard requirement, this baseline energy use is compared to the energy use of all newer energy standard editions, *ASHRAE 90.1-2004* and *ASHRAE 90.1-2007*, as well as a "Low Energy Case" that increases building energy efficiency beyond *ASHRAE 90.1-2007*.

A 10-year study period is selected because it is assumed that few building owners are concerned about costs realized beyond a decade into the future. It is a conservative study period length because the median commercial building's lifetime is, at a minimum, 50 years.[4] It is assumed that the building maintains its energy efficiency performance throughout the study period, resulting in energy consumption remaining constant over the entire study period. This assumption is reasonable given the maintenance, repair, and replacement costs included in the analysis to ensure the building and its equipment perform as expected.

This study assumes that cooling equipment is run on electricity while heating equipment is run on natural gas. The most significant increases in heating and cooling equipment efficiency requirements occur between *ASHRAE 90.1-1999* and *ASHRAE 90.1-2001* except for rooftop packaged units, which have consistently increasing requirements across multiple *ASHRAE Standard 90.1* editions. A lack of cost data for heating and cooling equipment led to a very conservative approach to estimating the cost of energy efficiency improvements for heating and cooling equipment. As a result, the additional costs associated with improving heating and cooling equipment energy efficiency is likely overestimated.

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[4] Buildings Energy Data Book (2011).

Natural gas accounts for 71 % of energy consumed to meet heating loads in commercial buildings in the U.S. in 2010[5], and for simplicity, assumed to be the fuel source for all buildings and locations for the BIRDS database. The use of natural gas for heating is more applicable for some locations than others due to the underlying conditions in a region, such as heating load and availability of fuel sources. According to the 2003 Commercial Buildings Energy Consumption Survey (CBECS) and shown in Table 1-1, the percentage of the floor area of heated buildings that consumes natural gas varies across CBECS Climate Zones and Census Divisions: 54.7 % to 77.7 % and 56.3 % to 85.9 %, respectively. For all categories, 50 % or more of the floor area consumes natural gas for heating.

Table 1-1 Fraction of Total Floor Space with Space Heating for which Natural Gas is an Energy Source by Census Division

CBECS Climate Zone	Fraction
Zone 1 (Coldest)	77.2 %
Zone 2	77.7 %
Zone 3	73.3 %
Zone 4	75.1 %
Zone 5 (Warmest)	54.7 %
Source: 2003 CBECS Table 7A, Table 8A, and Table 9A Note: CBECS Climate Zones are different than ASHRAE Climate Zones discussed in this report.	

Region	Division	Fraction
Northwest	New England	56.3 %
	Middle Atlantic	80.1 %
Midwest	East North Central	85.9 %
	West North Central	71.4 %
South	South Atlantic	57.9 %
	East South Central	74.5 %
	West South Central	67.9 %
West	Mountain	81.3 %
	Pacific	76.2 %
Source: 2003 CBECS Table 10A		

The changes in energy efficiency requirements across each edition of *ASHRAE 90.1* and the LEC design lead to unequal changes in energy performance across building components and can lead to a shift in fuel consumption from one fuel source to another (from electricity to natural gas and visa versa). For example, several energy efficiency measures adopted in the LEC design, including lower lighting power densities, daylighting, and overhangs, combine to reduce lighting loads while decreasing heat gains from both internal and external sources. As a result, electricity consumption decreases from lower lighting and cooling loads while increasing natural gas consumption to meet the larger heating load requirements.

Results are analyzed in both percentage and absolute value terms (‘Statewide Results’). The percentage savings results are based on a non-weighted average of the 11 building types, providing a relative impact of each standard edition. Additionally, where there is

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[5] Buildings Energy Data Book (2011).

significant variation, the percentage changes are used for comparisons across cities within each state (‘Within State Variation’). Variation increases with the land mass of the state, the number of climate zones in a state, and the number of cities within the state that have adopted energy codes that increase energy efficiency beyond the state energy code. The results for each state are summarized in the section ‘The Bottom Line.’

Results are aggregated at the state level to estimate the magnitude of total energy use savings, energy cost savings, present value (PV) life-cycle cost savings and energy-related carbon emissions (metric tons of carbon dioxide equivalent or CO_2e) reductions that could be attained by adoption of a more energy efficient state energy code. The non-weighted average savings per unit of floor area for all locations in a state for each of the 11 building types is multiplied by the average annual new floor area for that building type. The sum of the 11 building types is then divided by the fraction of the average total annual new building stock in the state because the eleven building types are assumed to be representative of the entire new building stock. Weighting the impacts by the amount of new construction for that building type can lead to total changes that differ in sign from the non-weighted average percentage changes. For example, a state could realize an average percentage reduction in life-cycle costs from the adoption of the LEC design, but realize an increase in total life-cycle costs because the building type with the greatest amount of new construction realizes large increases in life-cycle costs, overwhelming the life-cycle savings from building types for which it is cost-effective to adopt the LEC design.

There are a number of other assumptions made for this analysis. The building types selected for the BIRDS database were chosen for a number of reasons, including to show how the impacts of energy efficiency measures differ across a variety of buildings, including some less typical building designs (e.g., 100 % glazing). The new construction floor area data that is available is at the state level, which leads to an equal weighting of the cities included in the database and excludes the amount that each city contributes to new construction. The energy performance assumes 100 % enforcement of building energy codes, which overestimates the overall average energy performance of both the baseline and alternative building designs. A 3 % discount rate was selected for the analysis because that is the current rate for federal energy-related projects, which may be low or high depending on the investors time horizon and aversion to risk.

Given the assumptions required for this analysis, the results should be considered as general magnitude impacts instead of precise estimates. See the corresponding documents listed in Table 1-2 for additional information on the BIRDS database design, analysis, and results.

Table 1-2 Documentation of BIRDS Database Design and Analysis

Aspect of BIRDS Database	Document(s)	NIST Document #
Simulation Design	Kneifel 2011b	TN 1716
Life-Cycle Costing and Life-Cycle Assessment Approaches	Kneifel 2012	TN 1732
Database Analysis Capabilities	Kneifel 2013a	SP 1147
State-Level Results by Census Region	Kneifel 2013b,c,d.e	SP 1147-1, -2, -3, -4
Nationwide and Across State Analysis	Kneifel 2013f	SP 1161
SP = Special Publication TN = Technical Note		

2 Alaska

Alaska is the most northern state in the United States, located in *ASHRAE* Climate Zone 6, Zone 7, and Zone 8. Alaska has yet to adopt a state energy code for commercial building construction design and, for this analysis, is assumed to build to the current minimum industry practices represented by *ASHRAE 90.1-1999* requirements.

2.1 Statewide Results

Table 2-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 16.7 %, energy costs up to 27.6 %, and energy-related carbon emissions up to 24.0 %. Additionally, adopting *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or the LEC design leads to percentage reductions in life-cycle costs up to 1.0 %.

Table 2-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2001	2004	2007	LEC
Energy Use	-0.2	-0.8	-4.8	-16.7
Energy Cost	-0.4	-12.7	-14.3	-27.6
Carbon Emissions	-0.3	-8.9	-11.1	-24.0
Life-Cycle Cost	1.5	-0.5	-0.8	-1.0

Between 2003 and 2007, commercial and non-low-rise residential building construction in Alaska averaged 0.3 million m^2 (3.1 million ft^2) of new floor area annually. Table 2-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO$_2$e, and life-cycle costs in present value dollars (PV$) from adopting *ASHRAE 90.1-2007* or the LEC design as its state energy code over a 10-year study period for one year's worth of new construction. Adoption of *ASHRAE 90.1-2004* realizes an increase in energy consumption while decreasing energy costs, carbon emissions, and life-cycle costs.

Table 2-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2001	2004	2007	LEC
Energy Use	GWh	-1.1	1.9	-14.0	-99.4
Energy Cost	PV$Million	-$0.1	-$3.9	-$4.3	-$9.8
Carbon Emissions	1000 Metric tCO2e	-1	-18	-22	-58
Life-Cycle Cost	PV$Million	$3. 8	-$0.8	-$1.4	-$2.4

2.2 Within State Variation

Alaska is unique from other states in that it is the largest state by land mass and is located in the coldest climate zones in the United States. As a result, the heating load varies drastically across the state, which leads to significant variation in energy performance across cities within the same climate zone, particularly in the coldest climate zone (Zone 8). As shown in Table 2-3, buildings in Barrow realize an increase, on average, in energy consumption (10.8 %) from the adoption of *ASHRAE 90.1-2004* while buildings in Fairbanks and Nome realize a decrease in energy consumption (2.5 % and 2.1 %).

Table 2-3 Average Percentage Change from Adoption of *ASHRAE 90.1-2004* by City – 10 Yr Study Period

Cities	Zone	Metric			
		Energy Use	Energy Costs	Carbon Emissions	Life-Cycle Costs
Barrow	8	10.8	-4.4	1.2	0.4
Fairbanks	8	-2.5	-12.2	-8.5	-0.2
Nome	8	-2.1	-12.6	-8.7	-0.5

Assuming natural gas is used for heating in Alaska, the adoption of newer editions of *ASHRAE 90.1* lead to a shift in energy consumption from electricity to natural gas. In Alaska, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption. Table 2-3 shows the extreme case in Barrow, which realizes an overall increase in energy consumption of 10.8 % from the adoption of *ASHRAE 90.1-2004* while realizing a decrease in energy costs (-4.4 %) and smaller increase of carbon emissions (1.2 %) due to the shift in fuels.

2.3 The Bottom Line

Alaska could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting any edition of *ASHRAE 90.1*. If Alaska were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

3 Alabama

Alabama is located in the East South Central Census Division and spans two climate zones (Zone 2A and Zone 3A). The state does not have a commercial building energy code and, for this analysis, is assumed to build to the current minimum industry practices represented by *ASHRAE 90.1-1999* requirements.

3.1 Statewide Results

Table 3-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 33.6 %, energy costs up to 37.2 %, and energy-related carbon emissions up to 39.0 %. Additionally, adopting *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or the LEC design leads to percentage reductions in life-cycle costs up to 2.5 %.

Table 3-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2001	2004	2007	LEC
Energy Use	-1.8	-17.3	-19.9	-33.6
Energy Cost	-1.9	-19.4	-21.9	-37.2
Carbon Emissions	-2.0	-20.5	-22.9	-39.0
Life-Cycle Cost	2.0	-1.1	-1.5	-2.5

Assuming natural gas is used for heating in Alabama, the adoption of newer editions of *ASHRAE 90.1* lead to a shift in energy consumption from electricity to natural gas. In Alabama, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Between 2003 and 2007, commercial and non-low-rise residential building construction in Alabama averaged 2.3 million m^2 (24.3 million ft^2) of new floor area annually. Table 3-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO_2e, and life-cycle costs in present value dollars (PV$) from adopting the *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 3-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2001	2004	2007	LEC
Energy Use	GWh	-48.9	-518.4	-631.6	-1050.6
Energy Cost	PV$Million	-$3.9	-$42.5	-$49.8	-$84.9
Carbon Emissions	1000 Metric tCO2e	-41	-458	-528	-909
Life-Cycle Cost	PV$Million	$30.1	-$18.5	-$25.7	-$37.0

3.2 Within State Variation

Alabama is one of a few states in which one of its cities, Huntsville, has adopted a newer edition of *ASHRAE 90.1* as its state energy code (*ASHRAE 90.1-2001*). As a result, the percentage reductions in energy use, energy costs, and carbon emission, are smaller for Huntsville than for the other cities in the state, even those cities located in the same climate zone. As shown in Table 3-3, buildings in Huntsville realize a decrease, on average, in energy consumption of 13.5 % from the adoption of *ASHRAE 90.1-2007* while buildings in Birmingham and Montgomery realize a decrease in energy consumption of 17.8 % and 24.5 %, respectively.

Table 3-3 Average Percentage Change from Adoption of *ASHRAE 90.1-2007* by City – 10 Yr Study Period

Cities	Code	Zone	Metric			
			Energy Use	Energy Costs	Carbon Emissions	Life-Cycle Costs
Mobile	1999	2	-23.9	-24.1	-23.8	-2.2
Birmingham	1999	3	-17.8	-21.5	-22.7	-1.6
Huntsville	2001	3	-13.5	-18.1	-20.1	-3.8
Montgomery	1999	3	-24.5	-23.9	-23.4	-2.4

3.3 The Bottom Line

Alabama could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting any edition of *ASHRAE 90.1*. If Alabama were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

4 Arkansas

Arkansas is one of two states in the South Census Region that have adopted *ASHRAE 90.1-2001* as their state energy code for commercial buildings, is located in the West South Central Census Division, and spans two climate zones (Zone 3A and Zone 4A).

4.1 Statewide Results

Table 4-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 27.7 %, energy costs up to 33.9 %, and energy-related carbon emissions up to 36.1 % while decreasing life-cycle costs up to 3.3 %.

Table 4-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2004	2007	LEC
Energy Use	-12.8	-13.9	-27.7
Energy Cost	-16.5	-18.3	-33.9
Carbon Emissions	-17.8	-19.9	-36.1
Life-Cycle Cost	-2.4	-2.7	-3.3

Assuming natural gas is used for heating in Arkansas, the adoption of newer editions of *ASHRAE 90.1* leads to a shift in energy consumption from electricity to natural gas. In Arkansas, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Between 2003 and 2007, commercial and non-low-rise residential building construction in Arkansas averaged 1.2 million m^2 (12.8 million ft^2) of new floor area annually. Table 4-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO_2e, and life-cycle costs in present value dollars (PV$) from adopting the *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 4-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2004	2007	LEC
Energy Use	GWh	-173.6	-204.3	-426.1
Energy Cost	PV$Million	-$12.6	-$14.4	-$28.6
Carbon Emissions	1000 Metric tCO2e	-168	-190	-373
Life-Cycle Cost	PV$Million	-$17.7	-$17.5	-$20.4

4.2 The Bottom Line

Arkansas could benefit from the adoption of a more efficient state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting any edition of *ASHRAE 90.1*. If Arkansas were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building’s lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

5 Arizona

Arizona is located in the Mountain Census Division and spans four climate zones (Zone 2B, Zone 3B, Zone 4B, and Zone 5B). The state does not have a commercial building energy code and, for this analysis, is assumed to build to the current minimum industry practices represented by *ASHRAE 90.1-1999* requirements. However, it is common for cities in Arizona to adopt local energy codes for commercial buildings. Arizona is the only state in this study in which more than one city has adopted a local energy code that is two editions of *ASHRAE 90.1* (*-2004*) beyond its assumed baseline standard edition. For this reason, only results for *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, and the LEC design are included in this analysis. The estimated impacts for *ASHRAE 90.1-2004* are tempered since three of the six cities have already adopted that edition.

5.1 Statewide Results

Table 5-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or LEC design lead to percentage reductions in energy consumption up to 28.3 %, energy costs up to 31.2 %, and energy-related carbon emissions up to 31.9 %. Additionally, adopting *ASHRAE 90.1-2007* or the LEC design leads to percentage reductions in life-cycle costs up to 2.1 %.

Table 5-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2004	2007	LEC
Energy Use	-7.6	-12.9	-28.3
Energy Cost	-9.3	-12.8	-31.2
Carbon Emissions	-9.7	-12.8	-31.9
Life-Cycle Cost	0.2	-0.7	-2.1

Between 2003 and 2007, commercial and non-low-rise residential building construction in Arizona averaged 4.8 million m^2 (51.2 million ft^2) of new floor area annually. Table 5-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV\$), and energy-related carbon emissions in metric tCO_2e from adopting the *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or LEC design as its state energy code over a 10-year study period for one year’s worth of new construction. Additionally, the adoption of the *ASHRAE 90.1-2007* and LEC designs lead to reductions in life-cycle costs in present value dollars (PV\$).

Table 5-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2004	2007	LEC
Energy Use	GWh	-449.2	-946.3	-1857.5
Energy Cost	PV$Million	-$36.1	-$62.2	-$135.6
Carbon Emissions	1000 Metric tCO2e	-341	-562	-1255
Life-Cycle Cost	PV$Million	$15.8	-$30.8	-$79.1

5.2 Within State Variation

Arizona realizes significant variation in reductions in energy use, energy costs, and carbon emissions because three of the six cities have adopted their own local energy codes based on *ASHRAE 90.1-2004*. As shown in Table 5-3, buildings in Phoenix, Tucson, and Flagstaff realize smaller reductions in energy consumption than cities located in the same climate zone from the adoption of *ASHRAE 90.1-2007*.

Table 5-3 Average Percentage Change from Adoption of *ASHRAE 90.1-2007* by City – 10 Yr Study Period

Cities	Code	Zone	Metric			
			Energy Use	Energy Costs	Carbon Emissions	Life-Cycle Costs
Phoenix	2004	2B	-8.6	-6.7	-7.1	-1.5
Tucson	2004	2B	-8.7	-5.9	-6.0	-1.3
Yuma	1999	2B	-24.2	-24.1	-24.1	-1.1
Prescott	1999	4B	-16.1	-19.2	-19.6	0.1
Flagstaff	2004	5B	-3.7	-1.8	-1.6	-0.3
Winslow	1999	5B	-16.2	-19.1	-19.5	0.0

5.3 The Bottom Line

Even though the impacts vary significantly across the state, Arizona could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting any edition of *ASHRAE 90.1*. If Arizona were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

6 California

California has adopted the California Building Standards Code, otherwise known as Title 24. California's state energy code for commercial buildings is assumed to be *ASHRAE 90.1-2007* for this study because it is the edition of *ASHRAE 90.1* that most closely correlates to the requirements in Title 24. California is located in the Pacific Census Division, and spans five climate zones and seven subzones (Zone 2B, Zone 3B, Zone 3C, Zone 4B, Zone 4C, Zone 5B, and Zone 6B). Simulations are run for cities in Zone 3B, Zone 3C, and Zone 4B, which are the subzones that cover most of the state and contain the most significant population centers in California.

6.1 Statewide Results

Table 6-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (19.8 %), energy costs (24.5 %), and energy-related carbon emissions (22.6 %) while decreasing life-cycle costs (1.3 %). Assuming natural gas is used for heating in California, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In California, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 6-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-19.8
Energy Cost	-24.5
Carbon Emissions	-22.6
Life-Cycle Cost	-1.3

Between 2003 and 2007, commercial and non-low-rise residential building construction in California averaged 14.5 million m^2 (156.0 million ft^2) of new floor area annually. Table 6-2 shows that based on its average new construction, the state would realize reductions in energy consumption (2543 GWh), energy costs ($306 million), energy-related carbon emissions (1.4 million metric tons), and life-cycle costs ($125 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 6-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-2543.2
Energy Cost	PV$Million	-$305.6
Carbon Emissions	1000 Metric tCO2e	-1372
Life-Cycle Cost	PV$Million	-$124.9

6.2 Within State Variation

Cities considered in this study span across the state. As a result, there is variation in results across climate zones and across cities within climate zones in California. As shown in Table 6-3, buildings in Zone 3B realize the greatest average reductions in energy consumption (20.4 %) from the adoption of the LEC design followed by buildings in Zone 3C (17.5 %) and Zone 4B (14.3 %). The average reductions in energy consumption across cities within Zone 3B vary from 17.7 % in Sacramento to 25.1 % in San Diego with cities further south tending to realize greater reductions.

Table 6-3 Average Percentage Change from Adoption of the LEC design by Climate Zone and City – 10 Yr Study Period

Zone	Cities	Metric			
		Energy Use	**Energy Costs**	**Carbon Emissions**	**Life-Cycle Costs**
3B		**-20.4**	**-24.5**	**-23.4**	**-1.5**
	Bakersfield	-19.1	-22.8	-21.6	-1.4
	Daggett	-20.1	-23.0	-22.1	-1.4
	Fresno	-18.1	-23.0	-21.2	-1.6
	Long Beach	-23.8	-25.9	-25.4	-1.4
	Los Angeles	-24.4	-26.5	-26.0	-1.6
	Riverside	-20.7	-24.8	-23.4	-1.8
	Sacramento	-17.7	-23.4	-21.2	-1.4
	San Diego	-25.1	-26.3	-26.1	-1.4
3C		**-17.5**	**-25.0**	**-21.8**	**-0.6**
4B		**-14.3**	**-23.9**	**-19.4**	**-1.2**

6.3 The Bottom Line

California could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design would lead to reductions in total energy consumption, energy cost, and energy-related carbon emissions while decreasing total life-cycle costs. These are conservative estimates because a building’s lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

7 Colorado

Colorado is the only state in the West Census Region that has adopted *ASHRAE 90.1-2001* as its state energy code for commercial buildings, is located in the Mountain Census Division, and spans four climate zones (Zone 4B, Zone 5B, Zone 6B, and Zone 7).

7.1 Statewide Results

Table 7-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 23.5 %, energy costs up to 32.7 %, and energy-related carbon emissions up to 33.8 %. Additionally, adopting *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or the LEC design leads to percentage reductions in life-cycle costs up to 2.8 %.

Table 7-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2004	2007	LEC
Energy Use	-6.9	-10.4	-23.5
Energy Cost	-14.1	-15.2	-32.7
Carbon Emissions	-15.0	-15.8	-33.8
Life-Cycle Cost	-1.9	-2.2	-2.8

Assuming natural gas is used for heating in Colorado, the adoption of newer editions of *ASHRAE 90.1* leads to a shift in energy consumption from electricity to natural gas. In Colorado, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Between 2003 and 2007, commercial and non-low-rise residential building construction in Colorado averaged 3.3 million m^2 (35.4 million ft^2) of new floor area annually. Table 7-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO_2e, and life-cycle costs in present value dollars (PV$) from adopting the *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 7-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2004	2007	LEC
Energy Use	GWh	-308.8	-542.9	-1112.9
Energy Cost	PV$Million	-$30.6	-$35.0	-$72.7
Carbon Emissions	1000 Metric tCO_2e	-486	-541	-1 126
Life-Cycle Cost	PV$Million	-$46.1	-$53.9	-$59.7

7.2 Within State Variation

One city in Colorado, Grand Junction, has adopted its own state energy code based on *ASHRAE 90.1-2004*. As a result, Grand Junction realizes smaller reductions in energy use, energy costs, and carbon emissions than the other three cities within Zone 5B in Colorado. As shown in Table 7-3, buildings in Grand Junction realize a reduction in energy consumption of 3.2 % from the adoption of *ASHRAE 90.1-2007*, which is much lower than the reductions for the other three cities located in the same climate zone, which range from 12.4 % to 13.2 %.

Table 7-3 Average Percentage Change from Adoption of *ASHRAE 90.1-2007* by City – 10 Yr Study Period

Cities	Code	Zone	Metric			
			Energy Use	Energy Costs	Carbon Emissions	Life-Cycle Costs
Boulder	2001	5B	-12.5	-17.6	-18.0	-2.4
Colorado Springs	2001	5B	-12.4	-17.8	-18.1	-2.4
Grand Junction	2004	5B	-3.2	-1.1	-1.3	-0.4
Pueblo	2001	5B	-13.2	-17.7	-17.9	-2.6

7.3 The Bottom Line

Colorado could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting any edition of *ASHRAE 90.1*. If Colorado were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

8 Connecticut

Connecticut has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, and is located in the New England Census Division and Climate Zone 5A.

8.1 Statewide Results

Table 8-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (13.4 %), energy costs (21.5 %), and energy-related carbon emissions (18.7 %), and life-cycle costs (1.6 %). Assuming natural gas is used for heating in Connecticut, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Connecticut, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 8-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-13.4
Energy Cost	-21.5
Carbon Emissions	-18.7
Life-Cycle Cost	-1.6

Between 2003 and 2007, commercial and non-low-rise residential building construction in Connecticut averaged 1.4 million m^2 (15.5 million ft^2) of new floor area annually. Table 8-2 shows that based on its average new construction, the state would realize reductions in energy consumption (232 GWh), energy costs ($35 million), energy-related carbon emissions (161 000 metric tons), and life-cycle costs ($20 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 8-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-232.0
Energy Cost	PV$Million	-$35.1
Carbon Emissions	1000 Metric tCO_2e	-161
Life-Cycle Cost	PV$Million	-$19.7

8.2 The Bottom Line

Connecticut could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy cost, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

9 Delaware

Delaware has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, and is located in the South Atlantic Census Division and Climate Zone 4A.

9.1 Statewide Results

Table 9-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (14.8 %), energy costs (18.9 %), and energy-related carbon emissions (19.7 %), and life-cycle costs (1.9 %). Assuming natural gas is used for heating in Delaware, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Delaware, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 9-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-14.8
Energy Cost	-18.9
Carbon Emissions	-19.7
Life-Cycle Cost	-1.9

Between 2003 and 2007, commercial and non-low-rise residential building construction in Delaware averaged 0.3 million m^2 (3.7 million ft^2) of new floor area annually. Table 9-2 shows that based on its average new construction, the state would realize reductions in energy consumption (60 GWh), energy costs ($6.5 million), energy-related carbon emissions (45 000 metric tons), and life-cycle costs ($4.5 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 9-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-60.1
Energy Cost	PV$Million	-$6.5
Carbon Emissions	1000 Metric tCO_2e	-45
Life-Cycle Cost	PV$Million	-$4.5

9.2 The Bottom Line

Delaware could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy cost, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

10 Florida

Florida has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, is located in the South Atlantic Census Division, and spans two climate zones (Zone 1 and Zone 2A).

10.1 Statewide Results

Table 10-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (19.8 %), energy costs (20.9 %), and energy-related carbon emissions (21.0 %), and life-cycle costs (1.5 %). The percentage reductions are nearly identical for energy use, energy costs, and carbon emissions because the warm climate in Florida leads to minimal natural gas consumption for heating.

Table 10-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-19.8
Energy Cost	-20.9
Carbon Emissions	-21.0
Life-Cycle Cost	-1.5

Between 2003 and 2007, commercial and non-low-rise residential building construction in Florida averaged 16.5 million m^2 (178.1 million ft^2) of new floor area annually. Table 10-2 shows that based on its average new construction, the state would realize reductions in energy consumption (3790 GWh), energy costs ($333 million), energy-related carbon emissions (3 million metric tons), and life-cycle costs ($151 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 10-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-3790.5
Energy Cost	PV$Million	-$333.0
Carbon Emissions	1000 Metric tCO_2e	-3 230
Life-Cycle Cost	PV$Million	-$151.3

10.2 Within State Variation

Florida is a large state in terms of land mass and spans two climate zones. As a result, there is variation across cities in the reductions in energy use, energy costs, and carbon emissions. As shown in Table 10-3, buildings in Zone 1 realize a greater decrease, on average, in energy consumption of 21.3 % from the adoption of the LEC design while buildings in Zone 2 realize a decrease in energy consumption of 19.2 % with the cities that are further north realizing the smaller reductions.

Table 10-3 Average Percentage Change from Adoption of LEC by City – 10 Yr Study Period

Cities	Zone	Metric			
		Energy Use	Energy Costs	Carbon Emissions	Life-Cycle Costs
Key West	1	-21.3	-21.3	-22.1	-2.1
Miami	1	-21.2	-21.3	-22.0	-1.9
Daytona Beach	2A	-20.3	-21.4	-21.9	-1.4
Jacksonville	2A	-18.1	-20.4	-21.0	-1.1
Tallahassee	2A	-17.6	-20.5	-21.1	-1.1
Tampa	2A	-19.9	-20.8	-21.2	-1.5
West Palm Beach	2A	-20.3	-20.5	-20.9	-1.6

10.3 The Bottom Line

Even though the impacts vary across the state, Florida could benefit from the adoption of the LEC design as it's a state energy code. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

11 Georgia

Georgia has adopted *ASHRAE 90.1-2007* as its state energy code, is located in the South Atlantic Census Division, and spans two climate zones (Zone 2A and Zone 3A).

11.1 Statewide Results

Table 11-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (17.3 %), energy costs (20.2 %), and energy-related carbon emissions (21.2 %), and life-cycle costs (0.8 %). Assuming natural gas is used for heating in Georgia, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Georgia, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 11-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-17.3
Energy Cost	-20.2
Carbon Emissions	-21.2
Life-Cycle Cost	-0.8

Between 2003 and 2007, commercial and non-low-rise residential building construction in Georgia averaged 7.2 million m^2 (77.9 million ft^2) of new floor area annually. Table 11-2 shows that based on its average new construction, the state would realize reductions in energy consumption (4603 GWh), energy costs ($103 million), energy-related carbon emissions (1.3 million metric tons), and life-cycle costs ($28.5 million) from adopting the LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 11-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-4602.7
Energy Cost	PV$Million	-$102.5
Carbon Emissions	1000 Metric tCO_2e	-1250
Life-Cycle Cost	PV$Million	-$28.5

11.2 The Bottom Line

Georgia could benefit from the adoption of the LEC design as it’s a state energy code, Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to reductions in energy consumption, energy cost, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building’s lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

12 Hawaii

Hawaii is one of two states in the West Census Region that have adopted *ASHRAE 90.1-2004* as their state energy code for commercial buildings, is located in the Pacific Census Division, and is the only state solely located in the warmest climate zone (Zone 1).

12.1 Statewide Results

Table 12-1 shows that, on average, adopting *ASHRAE 90.1-2007* or the LEC design lead to percentage reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs with the LEC design leading to much greater percentage reductions. The percentage reductions are the same for energy use, energy costs, and carbon emissions because there is no natural gas consumption for heating; all energy use is from electricity consumption.

Table 12-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2007	LEC
Energy Use	-1.1	-23.1
Energy Cost	-1.1	-23.1
Carbon Emissions	-1.1	-23.1
Life-Cycle Cost	-0.2	-3.1

Between 2003 and 2007, commercial and non-low-rise residential building construction in Hawaii averaged 0.5 million m^2 (5.8 million ft^2) of new floor area annually. Table 12-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO_2e, and life-cycle costs in present value dollars (PV$) from adopting the *ASHRAE 90.1-2007* or LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 12-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2007	LEC
Energy Use	GWh	-12.1	-138.4
Energy Cost	PV$Million	-$2.1	-$23.9
Carbon Emissions	1000 Metric tCO_2e	-11	-124
Life-Cycle Cost	PV$Million	-$2.0	-$13.9

12.2 The Bottom Line

Hawaii could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting *ASHRAE 90.1-2007*. If Hawaii were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

13 Idaho

Idaho has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, is located in the Mountain Census Division, and spans two climate zones (Zone 5B and Zone 6B).

13.1 Statewide Results

Table 13-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (14.3 %), energy costs (18.0 %), and energy-related carbon emissions (18.1 %), and life-cycle costs (0.4 %). Assuming natural gas is used for heating in Idaho, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Idaho, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 13-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-14.3
Energy Cost	-18.0
Carbon Emissions	-18.1
Life-Cycle Cost	-0.4

Between 2003 and 2007, commercial and non-low-rise residential building construction in Idaho averaged 0.8 million m^2 (8.6 million ft^2) of new floor area annually. Table 13-2 shows that based on its average new construction, the state would realize reductions in energy consumption (140 GWh), energy costs ($7.6 million), energy-related carbon emissions (70 000 metric tons), and life-cycle costs ($1.5 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 13-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-139.9
Energy Cost	PV$Million	-$7.6
Carbon Emissions	1000 Metric tCO_2e	-70
Life-Cycle Cost	PV$Million	-$1.5

13.2 The Bottom Line

Idaho could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy cost, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building’s lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

14 Illinois

Illinois has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, is located in the East North Central Census Division, and spans two climate zones (Zone 4A and Zone 5A).

14.1 Statewide Results

Table 14-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (13.1 %), energy costs (20.3 %), and energy-related carbon emissions (20.3 %), and life-cycle costs (0.9 %). Assuming natural gas is used for heating in Illinois, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Illinois, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 14-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-13.1
Energy Cost	-20.3
Carbon Emissions	-20.3
Life-Cycle Cost	-0.9

Between 2003 and 2007, commercial and non-low-rise residential building construction in Illinois averaged 6.9 million m^2 (74.6 million ft^2) of new floor area annually. Table 14-2 shows that based on its average new construction, the state would realize reductions in energy consumption (1213 GWh), energy costs ($124 million), energy-related carbon emissions (1.3 million metric tons), and life-cycle costs ($31 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 14-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-1212.7
Energy Cost	PV$Million	-$124.4
Carbon Emissions	1000 Metric tCO_2e	-1343
Life-Cycle Cost	PV$Million	-$31.4

14.2 The Bottom Line

Illinois could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy cost, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

15 Indiana

Indiana has adopted *ASHRAE 90.1-2007* as its state energy code, is located in the East North Central Census Division, and spans two climate zones (Zone 4A and Zone 5A).

15.1 Statewide Results

Table 15-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (13.9 %), energy costs (19.5 %), and energy-related carbon emissions (20.5 %), and life-cycle costs (0.6 %). Assuming natural gas is used for heating in Indiana, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Indiana, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 15-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-13.9
Energy Cost	-19.5
Carbon Emissions	-20.5
Life-Cycle Cost	-0.6

Between 2003 and 2007, commercial and non-low-rise residential building construction in Indiana averaged 3.7 million m^2 (39.4 million ft^2) of new floor area annually. Table 15-2 shows that based on its average new construction, the state would realize reductions in energy consumption (657 GWh), energy costs ($50 million), energy-related carbon emissions (653 000 metric tons), and life-cycle costs ($13.3 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 15-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-656.9
Energy Cost	PV$Million	-$49.8
Carbon Emissions	1000 Metric tCO_2e	-653
Life-Cycle Cost	PV$Million	-$13.3

15.2 The Bottom Line

Indiana could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building’s lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

16 Iowa

Iowa has adopted *ASHRAE 90.1-2007* as its state energy code, is located in the West North Central Census Division, and spans two climate zones (Zone 5A and Zone 6A).

16.1 Statewide Results

Table 16-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (13.2 %), energy costs (18.2 %), and energy-related carbon emissions (19.0 %), and life-cycle costs (0.5 %). Assuming natural gas is used for heating in Iowa, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Iowa, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 16-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-13.2
Energy Cost	-18.2
Carbon Emissions	-19.0
Life-Cycle Cost	-0.5

Between 2003 and 2007, commercial and non-low-rise residential building construction in Iowa averaged 1.4 million m^2 (15.6 million ft^2) of new floor area annually. Table 16-2 shows that based on its average new construction, the state would realize reductions in energy consumption (284 GWh), energy costs ($17.6 million), energy-related carbon emissions (256 000 metric tons), and life-cycle costs ($4.0 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 16-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-283.7
Energy Cost	PV$Million	-$17.6
Carbon Emissions	1000 Metric tCO_2e	-256
Life-Cycle Cost	PV$Million	-$4.0

16.2 The Bottom Line

Iowa could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

17 Kansas

Kansas is located in the West North Central Census Division and spans two climate zones (Zone 4A and Zone 5A). The state does not have a commercial building energy code and, for this analysis, is assumed to build to the current minimum industry practices represented by *ASHRAE 90.1-1999* requirements.

17.1 Statewide Results

Table 17-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 26.3 %, energy costs up to 33.5 %, and energy-related carbon emissions up to 36.1 %. However, only adopting the LEC design leads to percentage reductions in life-cycle costs.

Table 17-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2001	2004	2007	LEC
Energy Use	-1.5	-10.3	-13.3	-26.3
Energy Cost	-1.7	-15.8	-17.1	-33.5
Carbon Emissions	-1.8	-17.8	-18.4	-36.1
Life-Cycle Cost	2.7	0.5	0.1	-0.7

Assuming natural gas is used for heating in Kansas, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Kansas, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Between 2003 and 2007, commercial and non-low-rise residential building construction in Kansas averaged 1.1 million m^2 (11.6 million ft^2) of new floor area annually. Table 17-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), and energy-related carbon emissions in metric tCO_2efrom adopting the *ASHRAE 90.1-2001*, *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or LEC design as its state energy code over a 10-year study period for one year’s worth of new construction. Adoption of each of the new editions of *ASHRAE 90.1* increase life-cycle costs while adopting the LEC design decreases life-cycle costs.

Table 17-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2001	2004	2007	LEC
Energy Use	GWh	-23.4	-145.7	-229.5	-438.6
Energy Cost	PV$Million	-$1.5	-$11.7	-$13.9	-$28.6
Carbon Emissions	1000 Metric tCO_2e	-23	-188	-208	-436
Life-Cycle Cost	PV$Million	$22.3	$6.9	$2.9	-$2.3

17.2 The Bottom Line

Kansas could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater energy consumption, energy cost, and energy-related carbon emissions than adopting any edition of *ASHRAE 90.1* while decreasing life-cycle costs. The additional energy efficiency measures adopted by the LEC design lead to enough energy cost savings to offset the associated energy efficiency investment costs. If Kansas were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission, but life-cycle costs would increase because there is not enough energy cost savings to offset the energy efficiency investment costs. These are conservative estimates because a building’s lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up. As a result, the adoption of *ASHRAE 90.1-2007* may become cost-effective as the investment time horizon is extended further into the future.

18 Kentucky

Kentucky has adopted *ASHRAE 90.1-2007* as its state energy code, and is located in the East South Central Census Division and Climate Zone 4A.

18.1 Statewide Results

Table 18-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (15.5 %), energy costs (19.3 %), and energy-related carbon emissions (21.3 %), and life-cycle costs (0.8 %). Assuming natural gas is used for heating in Kentucky, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Kentucky, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 18-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-15.5
Energy Cost	-19.3
Carbon Emissions	-21.3
Life-Cycle Cost	-0.8

Between 2003 and 2007, commercial and non-low-rise residential building construction in Kentucky averaged 2.0 million m^2 (21.0 million ft^2) of new floor area annually. Table 18-2 shows that based on its average new construction, the state would realize reductions in energy consumption (378 GWh), energy costs ($25 million), energy-related carbon emissions (341 000 metric tons), and life-cycle costs ($10 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 18-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-378.0
Energy Cost	PV$Million	-$24.6
Carbon Emissions	1000 Metric tCO_2e	-341
Life-Cycle Cost	PV$Million	-$9.8

18.2 The Bottom Line

Kentucky could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

19 Louisiana

Louisiana has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, is located in the West South Central Census Division, and spans two climate zones (Zone 2A and Zone 3A).

19.1 Statewide Results

Table 19-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (17.9 %), energy costs (20.0 %), and energy-related carbon emissions (20.7 %), and life-cycle costs (0.6 %). Assuming natural gas is used for heating in Louisiana, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Louisiana, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 19-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-17.9
Energy Cost	-20.0
Carbon Emissions	-20.7
Life-Cycle Cost	-0.6

Between 2003 and 2007, commercial and non-low-rise residential building construction in Louisiana averaged 1.7 million m^2 (18.3 million ft^2) of new floor area annually. Table 19-2 shows that based on its average new construction, the state would realize reductions in energy consumption (325 GWh), energy costs ($21 million), energy-related carbon emissions (270 000 metric tons), and life-cycle costs ($3 million) from adopting the LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 19-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-324.6
Energy Cost	PV$Million	-$20.8
Carbon Emissions	1000 Metric tCO_2e	-270
Life-Cycle Cost	PV$Million	-$3.2

19.2 The Bottom Line

Louisiana could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

20 Maine

Maine is located in the coldest climate zones in the contiguous U.S. (Zone 6 and Zone 7). The state does not have a commercial building energy code and, for this analysis, is assumed to build to the current minimum industry practices represented by *ASHRAE 90.1-1999* requirements.

20.1 Statewide Results

Table 20-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 23.1 %, energy costs up to 29.9 %, and energy-related carbon emissions up to 29.4 %. Additionally, adopting *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or the LEC design leads to percentage reductions in life-cycle costs.

Table 20-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2001	2004	2007	LEC
Energy Use	-0.7	-6.2	-11.4	-23.1
Energy Cost	-1.0	-13.8	-16.4	-29.9
Carbon Emissions	-0.9	-13.3	-16.0	-29.4
Life-Cycle Cost	2.1	-0.2	-0.8	-1.7

Assuming natural gas is used for heating in Maine, the adoption of newer editions of *ASHRAE 90.1* leads to a shift in energy consumption from electricity to natural gas. In Maine, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Between 2003 and 2007, commercial and non-low-rise residential building construction in Maine averaged 0.5 million m^2 (5.3 million ft^2) of new floor area annually. Table 20-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO_2e, and life-cycle costs in present value dollars (PV$) from adopting the *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 20-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2001	2004	2007	LEC
Energy Use	GWh	-5.6	-47.0	-105.5	-216.6
Energy Cost	PV$Million	-$0.5	-$7.3	-$9.4	-$18.0
Carbon Emissions	1000 Metric tCO_2e	-3	-45	-59	-113
Life-Cycle Cost	PV$Million	$7.9	-$1.3	-$3.3	-$6.4

20.2 The Bottom Line

Maine could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater energy consumption, energy cost, energy-related carbon emissions, and life-cycle costs than adopting any edition of *ASHRAE 90.1*. The additional energy efficiency measures adopted by the LEC design lead to enough energy cost savings to offset the associated energy efficiency investment costs. If Maine were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

21 Maryland

Maryland is located in the South Atlantic Census Division and primarily in Climate Zone 4A, with the northwestern portion of the state located in Zone 5A. Only one city, Baltimore, is simulated for this study and is located in Zone 4A. While Maryland is now the first state to adopt *ASHRAE 90.1-2010*, at the time of this study the state had adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings.

21.1 Statewide Results

Table 21-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (15.1 %), energy costs (20.6 %), and energy-related carbon emissions (20.0 %), and life-cycle costs (1.6 %). Assuming natural gas is used for heating in Maryland, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Maryland, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 21-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-15.1
Energy Cost	-20.6
Carbon Emissions	-20.0
Life-Cycle Cost	-1.6

Between 2003 and 2007, commercial and non-low-rise residential building construction in Maryland averaged 3.4 million m^2 (36.4 million ft^2) of new floor area annually. Table 21-2 shows that based on its average new construction, the state would realize reductions in energy consumption (622 GWh), energy costs ($62 million), energy-related carbon emissions (449 000 metric tons), and life-cycle costs ($29 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 21-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-622.2
Energy Cost	PV$Million	-$62.4
Carbon Emissions	1000 Metric tCO_2e	-449
Life-Cycle Cost	PV$Million	-$28.8

21.2 The Bottom Line

Maryland could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

22 Massachusetts

Massachusetts has adopted *ASHRAE 90.1-2007* as its state energy code, and is located in the New England Census Division and Climate Zone 5A.

22.1 Statewide Results

Table 22-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (12.9 %), energy costs (20.0 %), and energy-related carbon emissions (18.3 %), and life-cycle costs (1.1 %). Assuming natural gas is used for heating in Massachusetts, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Massachusetts, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 22-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-12.9
Energy Cost	-20.0
Carbon Emissions	-18.3
Life-Cycle Cost	-1.1

Between 2003 and 2007, commercial and non-low-rise residential building construction in Massachusetts averaged 2.6 million m^2 (27.8 million ft^2) of new floor area annually. Table 22-2 shows that based on its average new construction, the state would realize reductions in energy consumption (404 GWh), energy costs ($56 million), energy-related carbon emissions (277 000 metric tons), and life-cycle costs ($13 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 22-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-403.8
Energy Cost	PV$Million	-$56.0
Carbon Emissions	1000 Metric tCO_2e	-277
Life-Cycle Cost	PV$Million	-$12.8

22.2 The Bottom Line

Massachusetts could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building’s lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

23 Michigan

Michigan is located in the East North Central Census Division and has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings. Michigan spans three climate zones with the southern portion of the state located in Zone 5A, the central portion in Zone 6A, and the northern portion in Zone 7.

23.1 Statewide Results

Table 23-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (12.0 %), energy costs (17.9 %), and energy-related carbon emissions (18.7 %), and life-cycle costs (0.8 %). Assuming natural gas is used for heating in Michigan, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Michigan, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 23-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-12.0
Energy Cost	-17.9
Carbon Emissions	-18.7
Life-Cycle Cost	-0.8

Between 2003 and 2007, commercial and non-low-rise residential building construction in Michigan averaged 3.0 million m^2 (31.9 million ft^2) of new floor area annually. Table 23-2 shows that based on its average new construction, the state would realize reductions in energy consumption (512 GWh), energy costs ($40 million), energy-related carbon emissions (491 000 metric tons), and life-cycle costs ($17 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 23-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-511.9
Energy Cost	PV$Million	-$40.4
Carbon Emissions	1000 Metric tCO_2e	-491
Life-Cycle Cost	PV$Million	-$17.0

23.2 The Bottom Line

Michigan could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

24 Minnesota

Minnesota is located in the West North Central Census Division, and spans two climate zones with the southern portion of the state located in Zone 6A and the northern portion in Zone 7. Minnesota is the only state in the Midwest Census Region that has adopted *ASHRAE 90.1-2004* as its state energy code for commercial buildings.

24.1 Statewide Results

Table 24-1 shows that, on average, adopting *ASHRAE 90.1-2007* or the LEC design leads to percentage reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs with the LEC design leading to much greater percentage reductions.

Table 24-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2007	LEC
Energy Use	-5.6	-17.7
Energy Cost	-2.8	-18.5
Carbon Emissions	-2.4	-18.6
Life-Cycle Cost	-0.4	-0.8

Assuming natural gas is used for heating in Minnesota, the adoption of *ASHRAE 90.1-2007* leads to a shift in energy consumption from natural gas to electricity. In Minnesota, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result the shift in consumption from natural gas to electricity leads to smaller percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption. The opposite occurs for the adoption of the LEC design, where there is a shift from electricity to natural gas and the percentage reduction is greater for energy costs and carbon emissions relative to energy consumption.

Between 2003 and 2007, commercial and non-low-rise residential building construction in Minnesota averaged 2.3 million m^2 (25.1 million ft^2) of new floor area annually. Table 24-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO_2e, and life-cycle costs in present value dollars (PV$) from adopting the *ASHRAE 90.1-2007* or LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 24-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2007	LEC
Energy Use	GWh	-282.7	-816.7
Energy Cost	PV$Million	-$6.0	-$33.5
Carbon Emissions	1000 Metric tCO_2e	-71	-444
Life-Cycle Cost	PV$Million	-$7.3	-$12.4

24.2 The Bottom Line

Minnesota could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting *ASHRAE 90.1-2007*. If Minnesota were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

25 Mississippi

Mississippi is located in the East South Central Census Division and primarily in Climate Zone 3A with the southern (Gulf Coast) counties of the state located in Zone 2A. All cities simulated for this study are located in Zone 3A. The state does not have a commercial building energy code and, for this analysis, is assumed to build to the current minimum industry practices represented by *ASHRAE 90.1-1999* requirements.

25.1 Statewide Results

Table 25-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 36.2 %, energy costs up to 38.9 %, and energy-related carbon emissions up to 39.0 %. Additionally, adopting *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or the LEC design leads to percentage reductions in life-cycle costs up to 1.9 %.

Table 25-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2001	2004	2007	LEC
Energy Use	-2.2	-18.4	-23.7	-36.2
Energy Cost	-2.4	-20.0	-23.4	-38.9
Carbon Emissions	-2.4	-20.1	-23.4	-39.0
Life-Cycle Cost	2.6	-0.4	-1.1	-1.9

Between 2003 and 2007, commercial and non-low-rise residential building construction in Mississippi averaged 1.3 million m^2 (13.5 million ft^2) of new floor area annually. Table 25-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO$_2$e, and life-cycle costs in present value dollars (PV$) from adopting the *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 25-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2001	2004	2007	LEC
Energy Use	GWh	-34.3	-336.8	-470.6	-689.6
Energy Cost	PV$Million	-$2.6	-$22.6	-$28.1	-$46.3
Carbon Emissions	1000 Metric tCO$_2$e	-26	-227	-281	-465
Life-Cycle Cost	PV$Million	$21.4	-$5.3	-$12.3	-$14.8

25.2 The Bottom Line

Mississippi could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting any edition of *ASHRAE 90.1*. The additional energy efficiency measures adopted by the LEC design lead to enough energy cost savings to offset the associated energy efficiency investment costs. If Mississippi were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

26 Missouri

Missouri is located in the West North Central Census Division, and spans two climate zones (Zone 4 and Zone 5). The state does not have a commercial building energy code and, for this analysis, is assumed to build to the current minimum industry practices represented by *ASHRAE 90.1-1999* requirements.

26.1 Statewide Results

Table 26-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 26.4 %, energy costs up to 31.9 %, and energy-related carbon emissions up to 35.6 %. Additionally, adopting the LEC design leads to a percentage reduction in life-cycle costs of 0.5 %.

Table 26-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2001	2004	2007	LEC
Energy Use	-1.2	-10.3	-13.2	-26.4
Energy Cost	-1.4	-14.6	-16.1	-31.9
Carbon Emissions	-1.5	-17.5	-18.0	-35.6
Life-Cycle Cost	2.3	0.5	0.2	-0.5

Assuming natural gas is used for heating in Missouri, the adoption of newer editions of *ASHRAE 90.1* lead to a shift in energy consumption from electricity to natural gas. In Missouri, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Between 2003 and 2007, commercial and non-low-rise residential building construction in Missouri averaged 2.4 million m^2 (25.4 million ft^2) of new floor area annually. Table 26-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), and energy-related carbon emissions in metric tCO_2e from adopting the *ASHRAE 90.1-2001*, *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or LEC design as its state energy code over a 10-year study period for one year's worth of new construction. Additionally, the reductions from adopting the *ASHRAE 90.1-2007* and LEC designs are obtained while decreasing life-cycle costs in present value dollars (PV$).

Table 26-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2001	2004	2007	LEC
Energy Use	GWh	-35.3	-345.1	-524.1	-984.7
Energy Cost	PV\$Million	-\$2.0	-\$24.0	-\$29.1	-\$56.9
Carbon Emissions	1000 Metric tCO_2e	-35	-455	-502	-1001
Life-Cycle Cost	PV\$Million	\$37.3	\$5.1	-\$1.9	-\$2.7

26.2 Within State Variation

One city in Missouri, St. Louis, has adopted its own state energy code based on *ASHRAE 90.1-2001*. As a result, St. Louis realizes smaller reductions in energy use, energy costs, and carbon emissions than the other three cities within Zone 4A in Missouri. As shown in Table 26-3, buildings in St. Louis realize a reduction in energy consumption of 9.0 % from the adoption of *ASHRAE 90.1-2004*, which is much lower than the reductions for the other three cities located in the same climate zone, which range from 10.3 % to 11.5 %. The relative difference is minimal because the energy efficiency requirements defined in *ASHRAE 90.1-1999* and *ASHRAE 90.1-2001* are nearly identical.

Table 26-3 Average Percentage Change from Adoption of *ASHRAE 90.1-2004* by City – 10 Yr Study Period

Cities	Zone	Metric			
		Energy Use	Energy Costs	Carbon Emissions	Life-Cycle Costs
Columbia	4A	-10.4	-14.9	-17.6	1.2
Kansas	4A	-10.3	-14.7	-17.1	1.4
Springfield	4A	-11.5	-15.7	-16.9	1.0
St. Louis	**4A**	**-9.0**	**-13.2**	**-15.4**	**-1.6**
Average		**-10.3**	**-14.6**	**-16.7**	**0.5**

26.3 The Bottom Line

Missouri could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting any edition of *ASHRAE 90.1*. If Missouri were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

27 Montana

Montana has adopted *ASHRAE 90.1-2007* as its state energy code, and is located in the Mountain Census Division and Climate Zone 6B.

27.1 Statewide Results

Table 27-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (13.3 %), energy costs (16.7 %), and energy-related carbon emissions (16.3 %), and life-cycle costs (0.4 %). Assuming natural gas is used for heating in Montana, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Montana, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 27-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-13.3
Energy Cost	-16.7
Carbon Emissions	-16.3
Life-Cycle Cost	-0.4

Between 2003 and 2007, commercial and non-low-rise residential building construction in Montana averaged 0.2 million m^2 (2.6 million ft^2) of new floor area annually. Table 27-2 shows that based on its average new construction, the state would realize reductions in energy consumption (52 GWh), energy costs ($2.9 million), energy-related carbon emissions (24 000 metric tons), and life-cycle costs ($523 393) from adopting the LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 27-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-52.5
Energy Cost	PV$Million	-$2.9
Carbon Emissions	1000 Metric tCO_2e	-24
Life-Cycle Cost	PV$Million	-$0.5

27.2 The Bottom Line

Montana could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

28 Nebraska

Nebraska has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, and is located in the West North Central Census Division and Climate Zone 5A.

28.1 Statewide Results

Table 28-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (13.7 %), energy costs (19.9 %), and energy-related carbon emissions (20.7 %), and life-cycle costs (0.5 %). Assuming natural gas is used for heating in Nebraska, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Nebraska, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 28-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-13.7
Energy Cost	-19.9
Carbon Emissions	-20.7
Life-Cycle Cost	-0.5

Between 2003 and 2007, commercial and non-low-rise residential building construction in Nebraska averaged 0.9 million m^2 (9.9 million ft^2) of new floor area annually. Table 28-2 shows that based on its average new construction, the state would realize reductions in energy consumption (171 GWh), energy costs ($11 million), energy-related carbon emissions (167 000 metric tons), and life-cycle costs ($1.4 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 28-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-170.8
Energy Cost	PV$Million	-$11.0
Carbon Emissions	1000 Metric tCO_2e	-167
Life-Cycle Cost	PV$Million	-$1.4

28.2 The Bottom Line

Nebraska could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building’s lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

29 Nevada

Nevada is one of two states in the West Census Region that have adopted *ASHRAE 90.1-2004* as their state energy code for commercial buildings, is located in the Mountain Census Division, and spans two climate zones (Zone 3B and Zone 4B).

29.1 Statewide Results

Table 29-1 shows that, on average, adopting *ASHRAE 90.1-2007* or the LEC design lead to percentage reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs with the LEC design leading to much greater percentage reductions.

Table 29-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2007	LEC
Energy Use	-3.4	-17.8
Energy Cost	-1.7	-22.4
Carbon Emissions	-2.2	-21.0
Life-Cycle Cost	-0.4	-1.6

Assuming natural gas is used for heating in Nevada, the adoption of *ASHRAE 90.1-2007* newer editions of *ASHRAE 90.1* leads to a shift in energy consumption from natural gas to electricity. In Nevada, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result the shift in consumption from natural gas to electricity leads to smaller percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption. The opposite occurs for the adoption of the LEC design, where there is a shift from electricity to natural gas and the percentage reduction is greater for energy costs and carbon emissions relative to energy consumption.

Between 2003 and 2007, commercial and non-low-rise residential building construction in Nevada averaged 3.5 million m^2 (37.8 million ft^2) of new floor area annually. Table 29-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO_2e, and life-cycle costs in present value dollars (PV$) from adopting the *ASHRAE 90.1-2007* or LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 29-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2007	LEC
Energy Use	GWh	-117.3	-709.0
Energy Cost	PV$Million	-$2.9	-$59.7
Carbon Emissions	1000 Metric tCO_2e	-25	-327
Life-Cycle Cost	PV$Million	-$6.3	-$17.9

29.2 The Bottom Line

Nevada could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting *ASHRAE 90.1-2007*. If Nevada were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

30 New Hampshire

New Hampshire is located in the New England Census Division and has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings. New Hampshire spans two climate zones with the southern portion of the state located in Zone 5A and the northern portion in Zone 6A. Only one city, Concord, is simulated for this study and is located in Zone 6A.

30.1 Statewide Results

Table 30-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (12.8 %), energy costs (16.7 %), and energy-related carbon emissions (16.0 %), and life-cycle costs (1.4 %). Assuming natural gas is used for heating in New Hampshire, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In New Hampshire, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 30-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-12.8
Energy Cost	-16.7
Carbon Emissions	-16.0
Life-Cycle Cost	-1.4

Between 2003 and 2007, commercial and non-low-rise residential building construction in New Hampshire averaged 0.6 million m^2 (5.9 million ft^2) of new floor area annually. Table 30-2 shows that based on its average new construction, the state would realize reductions in energy consumption (108 GWh), energy costs ($10.9 million), energy-related carbon emissions (59 000 metric tons), and life-cycle costs ($5.8 million) from adopting the LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 30-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-108.0
Energy Cost	PV$Million	-$10.9
Carbon Emissions	1000 Metric tCO_2e	-59
Life-Cycle Cost	PV$Million	-$5.8

30.2 The Bottom Line

New Hampshire could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

31 New Jersey

New Jersey has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, and is located in the Middle Atlantic Census Division and Climate Zone 4A.

31.1 Statewide Results

Table 31-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (14.7 %), energy costs (21.2 %), and energy-related carbon emissions (19.7 %), and life-cycle costs (1.2 %). Assuming natural gas is used for heating in New Jersey, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In New Jersey, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 31-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-14.7
Energy Cost	-21.2
Carbon Emissions	-19.7
Life-Cycle Cost	-1.2

Between 2003 and 2007, commercial and non-low-rise residential building construction in New Jersey averaged 3.5 million m^2 (37.4 million ft^2) of new floor area annually. Table 31-2 shows that based on its average new construction, the state would realize reductions in energy consumption (582 GWh), energy costs ($73 million), energy-related carbon emissions (437 000 metric tons), and life-cycle costs ($21 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 31-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-581.6
Energy Cost	PV$Million	-$72.7
Carbon Emissions	1000 Metric tCO_2e	-437
Life-Cycle Cost	PV$Million	-$20.8

31.2 The Bottom Line

New Jersey could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

32 New Mexico

New Mexico has adopted *ASHRAE 90.1-2007* as its state energy code, is located in the Mountain Census Division, and spans three climate zones (Zone 3B, Zone 4B, and Zone 5B).

32.1 Statewide Results

Table 32-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (17.7 %), energy costs (22.9 %), and energy-related carbon emissions (22.9 %), and life-cycle costs (1.0 %). Assuming natural gas is used for heating in New Mexico, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In New Mexico, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 32-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-17.7
Energy Cost	-22.9
Carbon Emissions	-22.9
Life-Cycle Cost	-1.0

Between 2003 and 2007, commercial and non-low-rise residential building construction in New Mexico averaged 0.8 million m^2 (8.8 million ft^2) of new floor area annually. Table 32-2 shows that based on its average new construction, the state would realize reductions in energy consumption (154 GWh), energy costs ($11.7 million), energy-related carbon emissions (146 000 metric tons), and life-cycle costs ($5.5 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 32-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-153.7
Energy Cost	PV$Million	-$11.7
Carbon Emissions	1000 Metric tCO_2e	-146
Life-Cycle Cost	PV$Million	-$5.5

32.2 The Bottom Line

New Mexico could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

33 New York

New York has adopted *ASHRAE 90.1-2007* as its state energy code, is located in the Middle Atlantic Census Division, and spans three climate zones (Zone 4A, Zone 5A, and Zone 6A).

33.1 Statewide Results

Table 33-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (12.6 %), energy costs (19.7 %), and energy-related carbon emissions (16.7 %), and life-cycle costs (1.3 %). Assuming natural gas is used for heating in New York, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In New York, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 33-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-12.6
Energy Cost	-19.7
Carbon Emissions	-16.7
Life-Cycle Cost	-1.3

Between 2003 and 2007, commercial and non-low-rise residential building construction in New York averaged 6.1 million m^2 (65.3 million ft^2) of new floor area annually. Table 33-2 shows that based on its average new construction, the state would realize reductions in energy consumption (1038 GWh), energy costs ($132 million), energy-related carbon emissions (561 000 metric tons), and life-cycle costs ($37 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 33-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-1037.6
Energy Cost	PV$Million	-$132.5
Carbon Emissions	1000 Metric tCO_2e	-561
Life-Cycle Cost	PV$Million	-$37.1

33.2 Within State Variation

Cities considered in this study span across three climate zones, each of which has its own energy efficiency requirements for the LEC design. As a result, there is some variation in results across climate zones in New York. As shown in Table 33-3, buildings in the warmest climate zone (Zone 4A) realize the greatest average reductions in energy consumption (13.9 %) from the adoption of the LEC design followed by buildings in Zone 6A (12.7 %) and Zone 5A (12.2 %). There is minimal variation within climate zones (less than 1.0 %).

Table 33-3 Average Percentage Change from Adoption of the LEC design by Climate Zone and City – 10 Yr Study Period

Zone	Metric			
	Energy Use	Energy Costs	Carbon Emissions	Life-Cycle Costs
4A	-13.9	-21.4	-18.6	-1.2
5A	-12.2	-20.3	-17.0	-1.5
6A	-12.7	-17.7	-15.5	-1.2

33.3 The Bottom Line

New York could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

34 North Carolina

North Carolina is located in the South Atlantic Census Division and has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings. North Carolina spans three climate zones with the southern portion of the state located in Zone 3A, the central and northeast portions in Zone 4A, and the northwest portion in Zone 5A. All cities simulated for this study are located in Zone 3A and Zone 4A.

34.1 Statewide Results

Table 34-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (17.1 %), energy costs (20.1 %), and energy-related carbon emissions (21.0 %), and life-cycle costs (0.9 %). Assuming natural gas is used for heating in North Carolina, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In North Carolina, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 34-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-17.1
Energy Cost	-20.1
Carbon Emissions	-21.0
Life-Cycle Cost	-0.9

Between 2003 and 2007, commercial and non-low-rise residential building construction in North Carolina averaged 4.4 million m^2 (47.8 million ft^2) of new floor area annually. Table 34-2 shows that based on its average new construction, the state would realize reductions in energy consumption (828 GWh), energy costs ($56 million), energy-related carbon emissions (585 000 metric tons), and life-cycle costs ($20 million) from adopting the LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 34-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-827.9
Energy Cost	PV$Million	-$56.2
Carbon Emissions	1000 Metric tCO_2e	-585
Life-Cycle Cost	PV$Million	-$20.3

34.2 The Bottom Line

North Carolina could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

35 North Dakota

North Dakota is located in the West North Central Census Division and spans two climate zones (Zone 6 and Zone 7). The state does not have a commercial building energy code and, for this analysis, is assumed to build to the current minimum industry practices represented by *ASHRAE 90.1-1999* requirements.

35.1 Statewide Results

Table 35-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 21.2 %, energy costs up to 28.5 %, and energy-related carbon emissions up to 29.9 %. Additionally, adopting the LEC design leads to percentage reductions in life-cycle costs of 0.2 %.

Table 35-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2001	2004	2007	LEC
Energy Use	-0.8	-2.9	-8.9	-21.2
Energy Cost	-1.1	-11.7	-14.6	-28.5
Carbon Emissions	-1.2	-13.3	-15.7	-29.9
Life-Cycle Cost	2.1	0.7	0.1	-0.2

Assuming natural gas is used for heating in North Dakota, the adoption of newer editions of *ASHRAE 90.1* leads to a shift in energy consumption from electricity to natural gas. In North Dakota, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Between 2003 and 2007, commercial and non-low-rise residential building construction in North Dakota averaged 0.2 million m^2 (2.5 million ft^2) of new floor area annually. Table 35-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), and energy-related carbon emissions in metric tCO_2e from adopting a newer edition of *ASHRAE 90.1* or the LEC design as its state energy code over a 10-year study period for one year's worth of new construction. The reductions from the adoption of the *ASHRAE 90.1-2007* and LEC designs are realized without increasing life-cycle costs in present value dollars (PV$).

Table 35-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2001	2004	2007	LEC
Energy Use	GWh	-3.2	-12.9	-45.7	-104.5
Energy Cost	PV\$Million	-\$0.2	-\$1.7	-\$2.4	-\$4.8
Carbon Emissions	1000 Metric tCO_2e	-3	-29	-38	-76
Life-Cycle Cost	PV\$Million	\$3.4	\$0.8	-\$0.0	-\$0.0

For North Dakota, the amount of new building construction for each building type will impact the overall cost-effectiveness of adopting a state energy code. For example, the non-weighted average percentage change in life-cycle costs from adopting *ASHRAE 90.1-2007* implies a small increase in life-cycle costs (0.1 %). However, the building types that account for the most amount of new construction (retail stores, high schools, and hotels) each lead to life-cycle cost savings, which offset the impacts from the building types that increase life-cycle costs (3-story office buildings, 8-story office buildings and restaurants).

35.2 The Bottom Line

North Dakota could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater energy consumption, energy cost, and energy-related carbon emissions savings than adopting any edition of *ASHRAE 90.1*, and does so without increasing life-cycle costs. If North Dakota were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it would realize smaller savings in energy consumption, energy costs, and energy-related carbon emission, and also does not increase life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

36 Ohio

Ohio has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, is located in the East North Central Census Division, and spans two climate zones (Zone 4A and Zone 5A).

36.1 Statewide Results

Table 36-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (13.2 %), energy costs (19.2 %), and energy-related carbon emissions (20.2 %), and life-cycle costs (0.8 %). Assuming natural gas is used for heating in Ohio, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Ohio, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 36-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-13.2
Energy Cost	-19.2
Carbon Emissions	-20.2
Life-Cycle Cost	-0.8

Between 2003 and 2007, commercial and non-low-rise residential building construction in Ohio averaged 4.9 million m^2 (52.8 million ft^2) of new floor area annually. Table 36-2 shows that based on its average new construction the state would realize reductions in energy consumption (827 GWh), energy costs ($74 million), energy-related carbon emissions (838 000 metric tons), and life-cycle costs ($34 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 36-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-826.8
Energy Cost	PV$Million	-$74.1
Carbon Emissions	1000 Metric tCO_2e	-838
Life-Cycle Cost	PV$Million	-$33.9

36.2 The Bottom Line

Ohio could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

37 Oklahoma

Oklahoma is located in the West South Central Census Division and spans two climate zones, Zone 2A across most of the state and Zone 3B in the western "panhandle." The state does not have a commercial building energy code and, for this analysis, is assumed to build to the current minimum industry practices represented by *ASHRAE 90.1-1999* requirements.

37.1 Statewide Results

Table 37-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 27.0 %, energy costs up to 33.3 %, and energy-related carbon emissions up to 37.9 %. Additionally, adopting the LEC design leads to percentage reductions in life-cycle costs of 0.5 % while adopting *ASHRAE 90.1-2007* leads to no change in life-cycle costs.

Table 37-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2001	2004	2007	LEC
Energy Use	-2.0	-13.0	-13.9	-27.0
Energy Cost	-2.2	-17.0	-18.5	-33.3
Carbon Emissions	-2.3	-19.8	-21.9	-37.9
Life-Cycle Cost	2.5	0.3	0.0	-0.5

Between 2003 and 2007, commercial and non-low-rise residential building construction in Oklahoma averaged 1.6 million m^2 (17.1 million ft^2) of new floor area annually. Table 37-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), and energy-related carbon emissions in metric tCO$_2$e from adopting a newer edition of *ASHRAE 90.1* as its state energy code over a 10-year study period for one year's worth of new construction, but leads to an increase in life-cycle costs. The adoption of the LEC design not only realizes much larger reductions in energy use, energy costs, and carbon emissions, but does so while decreasing life-cycle costs in present value dollars (PV$).

Table 37-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2001	2004	2007	LEC
Energy Use	GWh	-38.1	-258.7	-300.5	-598.1
Energy Cost	PV$Million	-$2.0	-$16.6	-$18.6	-$35.4
Carbon Emissions	1000 Metric tCO$_2$e	-37	-330	-365	-679
Life-Cycle Cost	PV$Million	$26.2	$5.5	$5.7	-$0.7

37.2 The Bottom Line

Oklahoma could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting *ASHRAE 90.1-2007*. If Oklahoma were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings in energy consumption, energy costs, and energy-related carbon emission, but at an increase in life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up. As a result, the adoption of different editions of *ASHRAE 90.1* may become cost-effective as the investment time horizon is extended further into the future.

38 Oregon

Oregon has adopted *ASHRAE 90.1-2007* as its state energy code, is located in the Pacific Census Division, and spans two climate zones (Zone 4C and Zone 5B).

38.1 Statewide Results

Table 38-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (15.0 %), energy costs (19.1 %), energy-related carbon emissions (19.4 %), and life-cycle costs (0.6 %). Assuming natural gas is used for heating in Oregon, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Oregon, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 38-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-15.0
Energy Cost	-19.1
Carbon Emissions	-19.4
Life-Cycle Cost	-0.6

Between 2003 and 2007, commercial and non-low-rise residential building construction in Oregon averaged 1.7 million m^2 (18.8 million ft^2) of new floor area annually. Table 38-2 shows that based on its average new construction, the state would realize reductions in energy consumption (261 GWh), energy costs ($17.4 million), and energy-related carbon emissions (146 000 metric tons) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction. However, these reductions are realized with an increase in life-cycle costs of $400 000.

Table 38-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-261.4
Energy Cost	PV$Million	-$17.4
Carbon Emissions	1000 Metric tCO_2e	-146
Life-Cycle Cost	PV$Million	$0.4

For Oregon, the amount of new building construction for each building type impacts the overall cost-effectiveness of adopting the LEC design. The non-weighted average percentage change in life-cycle costs from adopting the LEC design implies a decrease in life-cycle costs (-0.6 %). However, three of the four building types that account for the most amount of new construction (retail stores, 4-story apartments, and 6-story apartments) lead to an increase in life-cycle costs while the fourth (hotels) only slightly decreases life-cycle costs. The total life-cycle cost savings from the other building types is not large enough to offset these increases in life-cycle costs. As a result, the net impact is a small increase in life-cycle costs.

38.2 The Bottom Line

Oregon could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to a reduction in energy consumption, energy costs, energy-related carbon emissions, but with an increase in life-cycle costs of $400 000. These are conservative estimates because a building’s lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up. As a result, the adoption of the LEC design may become cost-effective as the investment time horizon is extended further into the future.

39 Pennsylvania

Pennsylvania has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, is located in the Middle Atlantic Census Division, and spans three climate zones (Zone 4A, Zone 5A, and Zone 6A).

39.1 Statewide Results

Table 39-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (13.1 %), energy costs (18.3 %), energy-related carbon emissions (19.2 %), and life-cycle costs (0.7 %). Assuming natural gas is used for heating in Pennsylvania, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Pennsylvania, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 39-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-13.1
Energy Cost	-18.3
Carbon Emissions	-19.2
Life-Cycle Cost	-0.7

Between 2003 and 2007, commercial and non-low-rise residential building construction in Pennsylvania averaged 4.7 million m^2 (50.2 million ft^2) of new floor area annually. Table 39-2 shows that based on its average new construction, the state would realize reductions in energy consumption (765 GWh), energy costs ($64 million), energy-related carbon emissions (629 000 metric tons), and life-cycle costs ($18 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 39-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-764.9
Energy Cost	PV$Million	-$63.9
Carbon Emissions	1000 Metric tCO_2e	-629
Life-Cycle Cost	PV$Million	-$18.2

39.2 Within State Variation

Cities considered in this study span across three climate zones, each of which has its own energy efficiency requirements for the LEC design. As a result, there is some variation in results across climate zones and across cities within climate zones in Pennsylvania. As shown in Table 39-3, buildings in the warmest climate zone (Zone 4A) realize the greatest average reductions in energy consumption (14.6 %) from the adoption of the LEC design followed by buildings in Zone 5A (13.2 %) and Zone 6A (11.0 %). The average percentage reduction in energy consumption varies within Zone 5A from 12.4 % in Erie and Wilkes-Barre to 14.0 % in Harrisburg.

Table 39-3 Average Percentage Change from Adoption of the LEC design by Climate Zone and City – 10 Yr Study Period

Zone	City	Metric			
		Energy Use	Energy Costs	Carbon Emissions	Life-Cycle Costs
4A		**-14.6**	**-19.2**	**-20.2**	**-0.3**
5A		**-13.2**	**-18.4**	**-19.5**	**-0.7**
	Allentown	-13.6	-18.7	-19.8	-0.5
	Erie	-12.4	-17.8	-19.0	-0.7
	Harrisburg	-14.0	-18.9	-20.0	-0.7
	Pittsburgh	-13.7	-18.8	-19.9	-0.9
	Wilkes-Barre	-12.4	-17.8	-19.0	-0.8
	Williamsport	-13.1	-18.3	-19.4	-0.9
6A		**-11.0**	**-16.8**	**-18.1**	**-0.8**

39.3 The Bottom Line

Pennsylvania could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building’s lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

40 Rhode Island

Rhode Island has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, and is located in the New England Census Division. Only one city, Providence, is simulated for this study, and is located in Zone 5A.

40.1 Statewide Results

Table 40-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (13.4 %), energy costs (19.1 %), and energy-related carbon emissions (18.7 %), and life-cycle costs (1.2 %). Assuming natural gas is used for heating in Rhode Island, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Rhode Island, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 40-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-13.4
Energy Cost	-19.1
Carbon Emissions	-18.7
Life-Cycle Cost	-1.2

Between 2003 and 2007, commercial and non-low-rise residential building construction in Rhode Island averaged 0.3 million m^2 (3.6 million ft^2) of new floor area annually. Table 40-2 shows that based on its average new construction, the state would realize reductions in energy consumption (55 GWh), energy costs ($6.6 million), energy-related carbon emissions (38 000 metric tons), and life-cycle costs ($3.1 million) from adopting the LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 40-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-55.3
Energy Cost	PV$Million	-$6.6
Carbon Emissions	1000 Metric tCO_2e	-38
Life-Cycle Cost	PV$Million	-$3.1

40.2 The Bottom Line

Rhode Island could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

41 South Carolina

South Carolina is one of two states in the South Census Region that have adopted *ASHRAE 90.1-2004* as their state energy code for commercial buildings, and is located in the South Atlantic Census Division and Climate Zone 3A.

41.1 Statewide Results

Table 41-1 shows that, on average, adopting *ASHRAE 90.1-2007* or the LEC design lead to percentage reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs with the LEC design leading to much greater percentage reductions. Assuming natural gas is used for heating in South Carolina, the adoption of *ASHRAE 90.1-2007* or the LEC design lead to a shift in energy consumption from electricity to natural gas. In South Carolina, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 41-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2007	LEC
Energy Use	-1.8	-18.7
Energy Cost	-2.7	-22.4
Carbon Emissions	-2.9	-22.9
Life-Cycle Cost	-0.3	-0.9

Between 2003 and 2007, commercial and non-low-rise residential building construction in South Carolina averaged 2.7 million m^2 (29.3 million ft^2) of new floor area annually. Table 41-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO_2e, and life-cycle costs in present value dollars (PV$) from adopting the *ASHRAE 90.1-2007* or LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 41-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2007	LEC
Energy Use	GWh	-92.2	-594.5
Energy Cost	PV$Million	-$6.5	-$43.8
Carbon Emissions	1000 Metric tCO_2e	-61	-412
Life-Cycle Cost	PV$Million	-$2.9	-$12.2

41.2 The Bottom Line

South Carolina could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting *ASHRAE 90.1-2007*. If South Carolina were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

42 South Dakota

South Dakota is located in the West North Central Census Division, and spans two climate zones (Zone 5 and Zone 6). The state does not have a commercial building energy code and, for this analysis, is assumed to build to the current minimum industry practices represented by *ASHRAE 90.1-1999* requirements.

42.1 Statewide Results

Table 42-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 21.8 %, energy costs up to 29.5 %, and energy-related carbon emissions up to 30.6 %. Additionally, adopting *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or the LEC design leads to percentage reductions in life-cycle costs up to 1.3 %.

Table 42-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2001	2004	2007	LEC
Energy Use	-0.7	-6.5	-10.5	-21.8
Energy Cost	-0.9	-14.2	-15.7	-29.5
Carbon Emissions	-0.9	-15.2	-16.5	-30.6
Life-Cycle Cost	1.4	-0.6	-0.9	-1.3

Assuming natural gas is used for heating in South Dakota, the adoption of newer editions of *ASHRAE 90.1* leads to a shift in energy consumption from electricity to natural gas. In South Dakota, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Between 2003 and 2007, commercial and non-low-rise residential building construction in South Dakota averaged 0.3 million m^2 (3.3 million ft^2) of new floor area annually. Table 42-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO_2e, and life-cycle costs in present value dollars (PV$) from adopting the *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 42-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2001	2004	2007	LEC
Energy Use	GWh	-3.4	-29.0	-57.5	-122.3
Energy Cost	PV$Million	-$0.2	-$2.6	-$3.1	-$6.5
Carbon Emissions	1000 Metric tCO_2e	-3	-41	-48	-98
Life-Cycle Cost	PV$Million	$2.9	-$0.7	-$1.4	-$2.4

42.2 The Bottom Line

South Dakota could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting any edition of *ASHRAE 90.1*. If South Dakota were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

43 Tennessee

Tennessee is one of two states in the South Census Region that have adopted *ASHRAE 90.1-2004* as their state energy code for commercial buildings, is located in the East South Central Census Division, and spans two climate zones (Zone 3A and Zone 4A).

43.1 Statewide Results

Table 43-1 shows that, on average, adopting *ASHRAE 90.1-2007* or the LEC design lead to percentage reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs with the LEC design leading to much greater percentage reductions. Assuming natural gas is used for heating in Tennessee, the adoption of newer editions of *ASHRAE 90.1* leads to a shift in energy consumption from electricity to natural gas. In Tennessee, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 43-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2007	LEC
Energy Use	-2.3	-18.8
Energy Cost	-1.2	-21.9
Carbon Emissions	-1.0	-22.5
Life-Cycle Cost	-0.3	-1.4

Between 2003 and 2007, commercial and non-low-rise residential building construction in Tennessee averaged 3.3 million m^2 (35.2 million ft^2) of new floor area annually. Table 43-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO_2e, and life-cycle costs in present value dollars (PV$) from adopting *ASHRAE 90.1-2007* or the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 43-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2007	LEC
Energy Use	GWh	-172.6	-807.8
Energy Cost	PV$Million	-$6.5	-$58.7
Carbon Emissions	1000 Metric tCO_2e	-60	-627
Life-Cycle Cost	PV$Million	-$7.5	-$28.1

43.2 The Bottom Line

Tennessee could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting *ASHRAE 90.1-2007*. If Tennessee were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

44 Texas

Texas has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, is located in the West South Central Census Division, and spans three climate zones (Zone 2, Zone 3, and Zone 4).

44.1 Statewide Results

Table 44-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (17.8 %), energy costs (21.0 %), energy-related carbon emissions (21.1 %), and life-cycle costs (1.3 %). Assuming natural gas is used for heating in Texas, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Texas, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 44-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-17.8
Energy Cost	-21.0
Carbon Emissions	-21.1
Life-Cycle Cost	-1.3

Between 2003 and 2007, commercial and non-low-rise residential building construction in Texas averaged 14.4 million m^2 (155.5 million ft^2) of new floor area annually. Table 44-2 shows that based on its average new construction, the state would realize reductions in energy consumption (2832 GWh), energy costs ($234 million), energy-related carbon emissions (2.6 million metric tons), and life-cycle costs ($107 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 44-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-2831.6
Energy Cost	PV$Million	-$234.5
Carbon Emissions	1000 Metric tCO_2e	-2630
Life-Cycle Cost	PV$Million	-$106.8

44.2 Within State Variation

Texas is one of the largest states in terms of land mass and spans three climate zones, over both wet and dry subzones (Zone 2, Zone 3, and Zone 4), and such as, the reductions vary across climate zones. As shown in Table 44-3, there is not much difference, on average, across climate zones (16.8 % to 18.0 %). However, there is significant variation across cities in Texas, even within climate zones, For example, the energy use savings realized by cities within Zone 2 vary from 16.6 % in Waco to 19.5 % in Corpus Christi.

Table 44-3 Average Percentage Change from Adoption of LEC by City – 10 Yr Study Period

Zone	City	Metric			
		Energy Use	Energy Costs	Carbon Emissions	Life-Cycle Costs
Zone 2		**-18.0**	**-20.5**	**-20.8**	**-1.2**
2A	Austin	-17.2	-20.3	-20.6	-1.0
2A	Brownsville	-19.2	-20.1	-20.4	-1.5
2A	Corpus Christi	-19.5	-20.7	-21.0	-1.2
2A	Houston	-17.5	-20.3	-20.6	-1.1
2A	Lufkin	-17.3	-20.7	-21.1	-1.4
2A	Port Arthur	-17.9	-20.4	-20.8	-1.1
2A	San Antonio	-18.0	-21.0	-21.4	-1.1
2A	Victoria	-18.9	-20.7	-21.0	-1.3
2A	Waco	-16.6	-20.4	-20.8	-1.0
2B	Del Rio	-17.6	-20.0	-20.3	-1.6
Zone 3		**-17.8**	**-21.7**	**-22.0**	**-1.3**
Zone 4		**-16.8**	**-22.5**	**-22.8**	**-1.1**

44.3 The Bottom Line

Texas could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building’s lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

45 Utah

Utah has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, is located in the Mountain Census Division, and spans three climate zones (Zone 3B, Zone 5B, and Zone 6B).

45.1 Statewide Results

Table 45-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (15.1 %), energy costs (21.2 %), energy-related carbon emissions (19.6 %), and life-cycle costs (0.7 %). Assuming natural gas is used for heating in Utah, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Utah, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 45-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-15.1
Energy Cost	-21.2
Carbon Emissions	-19.6
Life-Cycle Cost	-0.7

Between 2003 and 2007, commercial and non-low-rise residential building construction in Utah averaged 1.7 million m^2 (18.5 million ft^2) of new floor area annually. Table 45-2 shows that based on its average new construction, the state would realize reductions in energy consumption (287 GWh), energy costs ($18.8 million), energy-related carbon emissions (144 000 metric tons), and life-cycle costs ($5.4 million) from adopting the LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 45-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-286.6
Energy Cost	PV$Million	-$18.8
Carbon Emissions	1000 Metric tCO_2e	-144
Life-Cycle Cost	PV$Million	-$5.4

45.2 The Bottom Line

Utah could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

46 Vermont

Vermont has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, and is located in the Northeast Census Division and Climate Zone 6A. Only one city, Burlington, is simulated for this study.

46.1 Statewide Results

Table 46-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (12.6 %), energy costs (16.4 %), energy-related carbon emissions (15.8 %), and life-cycle costs (1.2 %). Assuming natural gas is used for heating in Vermont, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Vermont, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 46-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-12.6
Energy Cost	-16.4
Carbon Emissions	-15.8
Life-Cycle Cost	-1.2

Between 2003 and 2007, commercial and non-low-rise residential building construction in Vermont averaged 0.2 million m^2 (2.1 million ft^2) of new floor area annually. Table 46-2 shows that based on its average new construction, the state would realize reductions in energy consumption (37 GWh), energy costs ($3.4 million), energy-related carbon emissions (21 000 metric tons), and life-cycle costs ($1.4 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 46-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-37.3
Energy Cost	PV$Million	-$3.4
Carbon Emissions	1000 Metric tCO_2e	-21
Life-Cycle Cost	PV$Million	-$1.4

46.2 The Bottom Line

Vermont could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building’s lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

47 Virginia

Virginia has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, and is located in the South Atlantic Census Division and Climate Zone 4A.

47.1 Statewide Results

Table 47-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (17.0 %), energy costs (20.8 %), energy-related carbon emissions (21.6 %), and life-cycle costs (0.8 %). Assuming natural gas is used for heating in Virginia, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Virginia, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 47-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-17.0
Energy Cost	-20.8
Carbon Emissions	-21.6
Life-Cycle Cost	-0.8

Between 2003 and 2007, commercial and non-low-rise residential building construction in Virginia averaged 4.5 million m^2 (48.4 million ft^2) of new floor area annually. Table 47-2 shows that based on its average new construction, the state would realize reductions in energy consumption (871 GWh), energy costs ($60 million), energy-related carbon emissions (695 000 metric tons), and life-cycle costs ($14 million) from adopting the LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 47-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-871.3
Energy Cost	PV$Million	-$60.5
Carbon Emissions	1000 Metric tCO_2e	-695
Life-Cycle Cost	PV$Million	-$14.0

47.2 The Bottom Line

Virginia could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

48 Washington

Washington has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, is located in the Pacific Census Division, and spans three climate zones (Zone 4C, Zone 5B, and Zone 6B).

48.1 Statewide Results

Table 48-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (13.6 %), energy costs (17.1 %), energy-related carbon emissions (18.1 %), and life-cycle costs (0.2 %). Assuming natural gas is used for heating in Washington, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Washington, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 48-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-13.6
Energy Cost	-17.1
Carbon Emissions	-18.1
Life-Cycle Cost	-0.2

Between 2003 and 2007, commercial and non-low-rise residential building construction in Washington averaged 3.7 million m^2 (39.9 million ft^2) of new floor area annually. Table 48-2 shows that based on its average new construction, the state would realize reductions in energy consumption (525 GWh), energy costs ($32 million), and energy-related carbon emissions (267 000 metric tons) from adopting the LEC design as its state energy code over a 10-year study period for one year’s worth of new construction, but does so with an increase in life-cycle costs of over $11 million.

Table 48-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-525.0
Energy Cost	PV$Million	-$32.3
Carbon Emissions	1000 Metric tCO_2e	-267
Life-Cycle Cost	PV$Million	$11.5

For Washington, the amount of new building construction for each building type impacts the overall cost-effectiveness of adopting the LEC design. The non-weighted average percentage change in life-cycle costs from adopting the LEC design implies a decrease in life-cycle costs (-0.2 %). However, the four building types that account for the most amount of new construction (retail stores, 6-story apartments, high schools, and 4-story apartments) lead to an increase in life-cycle costs, and overwhelm the impacts from the three building types that reduce life-cycle costs (3-story office buildings, 8-story office buildings, and restaurants).

48.2 The Bottom Line

Washington could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, and energy-related carbon emissions. However, these savings are realized with an increase in life-cycle costs of over $11 million. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up. As a result, the adoption of the LEC design may become cost-effective as the investment time horizon is extended further into the future.

49 West Virginia

West Virginia is one of two states in the South Census Region that have adopted *ASHRAE 90.1-2001* as their state energy code for commercial buildings, is located in the South Atlantic Census Division, and spans two climate zones (Zone 4A and Zone 5A).

49.1 Statewide Results

Table 49-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 25.7 %, energy costs up to 28.8 %, energy-related carbon emissions up to 34.6 %, and life-cycle costs up to 2.2 %. Assuming natural gas is used for heating in West Virginia, the adoption of newer editions of *ASHRAE 90.1* leads to a shift in energy consumption from electricity to natural gas. In West Virginia, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 49-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2004	2007	LEC
Energy Use	-9.9	-12.6	-25.7
Energy Cost	-12.2	-14.2	-28.8
Carbon Emissions	-16.6	-17.2	-34.6
Life-Cycle Cost	-1.6	-1.9	-2.2

Between 2003 and 2007, commercial and non-low-rise residential building construction in West Virginia averaged 0.5 million m^2 (5.2 million ft^2) of new floor area annually. Table 49-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), energy-related carbon emissions in metric tCO_2e, and life-cycle costs in present value dollars (PV$) from adopting the *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or LEC design as its state energy code over a 10-year study period for one year’s worth of new construction.

Table 49-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2004	2007	LEC
Energy Use	GWh	-58.7	-96.4	-177.2
Energy Cost	PV$Million	-$3.6	-$5.0	-$9.7
Carbon Emissions	1000 Metric tCO_2e	-68	-79	-161
Life-Cycle Cost	PV$Million	-$5.6	-$7.3	-$7.1

49.2 The Bottom Line

West Virginia could benefit from the adoption of a newer edition of ASHRAE 90.1 as its state energy code. Adopting *ASHRAE 90.1-2007* leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting *ASHRAE 90.1-2004*. If West Virginia were to adopt the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, it could realize even greater savings in energy consumption, energy costs, and energy-related carbon emission relative to *ASHRAE 90.1-2007*, but at slightly lower life-cycle cost savings. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up. Given a longer study period, the LEC design may become the most cost-effective building design alternative.

50 Wisconsin

Wisconsin has adopted *ASHRAE 90.1-2007* as its state energy code for commercial buildings, is located in the East North Central Census Region, and spans two climate zones (Zone 6A and Zone 7).

50.1 Statewide Results

Table 50-1 shows that, on average, adopting the LEC design leads to percentage reductions in energy consumption (12.6 %), energy costs (16.6 %), energy-related carbon emissions (16.9 %), and life-cycle costs (0.7 %). Assuming natural gas is used for heating in Wisconsin, the adoption of the LEC design leads to a shift in energy consumption from electricity to natural gas. In Wisconsin, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Table 50-1 Average Percentage Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	LEC
Energy Use	-12.6
Energy Cost	-16.6
Carbon Emissions	-16.9
Life-Cycle Cost	-0.7

Between 2003 and 2007, commercial and non-low-rise residential building construction in Wisconsin averaged 2.4 million m^2 (25.7 million ft^2) of new floor area annually. Table 50-2 shows that based on its average new construction, the state would realize reductions in energy consumption (491 GWh), energy costs ($33 million), energy-related carbon emissions (384 000 metric tons), and life-cycle costs ($15 million) from adopting the *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, or LEC design as its state energy code over a 10-year study period for one year's worth of new construction.

Table 50-2 Total Change from Adoption of the LEC Design – 10-Yr Study Period

Metric	Unit	LEC
Energy Use	GWh	-491.0
Energy Cost	PV$Million	-$33.2
Carbon Emissions	1000 Metric tCO_2e	-384
Life-Cycle Cost	PV$Million	-$14.9

50.2 The Bottom Line

Wisconsin could benefit from the adoption of the LEC design as its state energy code, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*. Adoption of the LEC design leads to reduction in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

51 Wyoming

Wyoming is located in the Mountain Census Division and spans three climate zones (Zone 5B, Zone 6B, and Zone 7). The state does not have a commercial building energy code and, for this analysis, is assumed to build to the current minimum industry practices represented by *ASHRAE 90.1-1999* requirements.

51.1 Statewide Results

Table 51-1 shows that, on average, adopting newer editions of *ASHRAE 90.1* or the LEC design lead to percentage reductions in energy consumption up to 23.8 %, energy costs up to 31.7 %, and energy-related carbon emissions up to 31.6 %. Additionally, adopting *ASHRAE 90.1-2007* or the LEC design leads to percentage reductions in life-cycle costs up to 0.5 %.

Table 51-1 Average Percentage Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	2001	2004	2007	LEC
Energy Use	-0.9	-7.6	-11.7	-23.8
Energy Cost	-1.1	-15.7	-17.4	-31.7
Carbon Emissions	-1.1	-15.6	-17.3	-31.6
Life-Cycle Cost	2.2	0.1	-0.3	-0.5

Assuming natural gas is used for heating in Wyoming, the adoption of newer editions of *ASHRAE 90.1* leads to a shift in energy consumption from electricity to natural gas. In Wyoming, natural gas is cheaper on a per-unit of energy basis and leads to less CO_2e emissions per unit of energy consumed. As a result, the shift in consumption from electricity to natural gas leads to greater percentage savings in both energy costs and carbon emissions than the percentage savings in energy consumption.

Between 2003 and 2007, commercial and non-low-rise residential building construction in Wyoming averaged 0.2 million m^2 (2.5 million ft^2) of new floor area annually. Table 51-2 shows that based on its average new construction, the state would realize reductions in energy consumption in GWh, energy costs in present value dollars (PV$), and energy-related carbon emissions in metric tCO_2e from adopting any edition of *ASHRAE 90.1* or the LEC design as its state energy code over a 10-year study period for one year's worth of new construction. Additionally, the savings from the adoption of *ASHRAE 90.1-2007* and the LEC design are realized while decreasing life-cycle costs in present value dollars (PV$).

Table 51-2 Total Change from Adoption of Newer Standards – 10-Yr Study Period

Metric	Unit	2001	2004	2007	LEC
Energy Use	GWh	-2.7	-22.0	-34.9	-76.6
Energy Cost	PV$Million	-$0.2	-$2.4	-$2.6	-$5.3
Carbon Emissions	1000 Metric tCO_2e	-2	-24	-27	-53
Life-Cycle Cost	PV$Million	$3.9	$0.2	-$0.5	-$0.7

51.2 The Bottom Line

Wyoming could benefit from the adoption of a state energy code, particularly by taking an aggressive approach at increasing new building energy efficiency requirements. Adopting the LEC design, which is based on the energy efficiency requirements defined in *ASHRAE 189.1-2009*, leads to greater reductions in energy consumption, energy costs, energy-related carbon emissions, and life-cycle costs than adopting any edition of *ASHRAE 90.1*. If Wyoming were to adopt a state energy code similar to the majority of states in the U.S. (*ASHRAE 90.1-2007*), it could still realize savings, although much smaller, in energy consumption, energy costs, and energy-related carbon emission while decreasing life-cycle costs. These are conservative estimates because a building's lifetime is significantly longer than the 10-year study period length. As the study period increases, operating energy becomes a more significant driver of overall costs, which will drive life-cycle cost savings up.

52 Limitations and Future Research

The analysis in this study is limited in scope and would be strengthened by including sensitivity analysis, expanding the BIRDS database and metrics, and enabling public access to all the results.

Sensitivity analysis is needed for at least two assumptions in the analysis. First, consider the assumed discount rate. Although 3 % is a reasonable discount rate, in real terms, for federal government investment decisions, it may be too low of a value for an expected real return on an alternative investment in the private sector. Sensitivity analysis on the assumed discount rate is needed to determine the robustness of the cost results. Second, the current analysis assumes that the cooling load is met by equipment running on electricity while heating loads are met with equipment running on natural gas, which is not the typical fuel mix for some areas of the nation. The BIRDS database should be expanded to include alternative fuel source options, such as heating oil use in the New England area or electric heating in the South.

Additional data are needed to refine and expand the BIRDS database. First, the study uses simple averages to summarize energy use, energy cost, life-cycle cost, and carbon emissions changes across all locations in a state. However, the amount of total floor area constructed will vary significantly from city to city. Future research could develop a weighted average of savings in a state based on the fraction of new construction by city. Second, the 11 prototypical buildings analyzed in this study are likely not representative of the entire building stock for each building type. For example, all high-rise buildings are not 100 % vertical fenestration. For this reason, the results should be considered as orders of magnitude instead of precise estimates. Future research should include additional prototypes in the database, such as the Department of Energy Commercial Reference Buildings. Additionally, since existing buildings account for nearly the entire building stock, prototypes for energy retrofits to buildings should be incorporated into the BIRDS database as well. The state average energy cost rates and energy-related carbon emissions rates do not control for local variation in energy tariffs or electricity fuel mixes. By using utility-level energy cost and emissions rate data, the accuracy of the estimates in the BIRDS database could be improved.

The analysis in this study ignores the impacts that occupant behavior, such as plug and process loads, have on the reductions in energy use. Buildings with greater plug and process loads will realize smaller percentage changes in energy use because the energy efficiency measures considered in this study focus on the building envelope and heating and cooling equipment, holding constant the energy use from other equipment used in the building. As building energy efficiency improves, the plug and process loads become a larger fraction of the overall energy load. Also, occupants may have different preferences for indoor conditions, such as higher or lower temperature setpoints, which will impact the energy consumption of the building. Future research should consider the impact the assumed occupant behaviors have on the overall energy savings realized by energy efficiency improvements to buildings.

This study only compares the current state energy code to newer, more stringent standard editions. The BIRDS database is much more expansive, allowing researchers to compare any of the editions of *ASHRAE 90.1* with any other edition of *ASHRAE 90.1* or the LEC design. The BIRDS database should be made available to the public through a simple-to-use software tool that allows other researchers to use the database for their own research on building energy efficiency.

Finally, a more comprehensive sustainability assessment of the benefits and costs of building energy efficiency would increase the impact of this work. This study would apply environmental life-cycle assessment methods to evaluate the global warming potentials attributable to building energy efficiency improvements. In a parallel effort, the BIRDS database is being expanded to include a full range of eleven life-cycle environmental impacts covering human health effects, ecological health effects, and resource depletion. The sustainability assessment is also being expanded beyond building energy efficiency to cover the materials used in construction, maintenance, repair, and replacement of building components, and waste management. The BIRDS software tool in development will provide the results of this more comprehensive sustainability assessment alongside the results summarized in this report.

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