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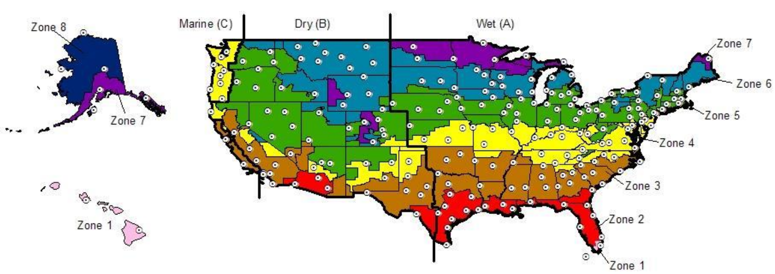
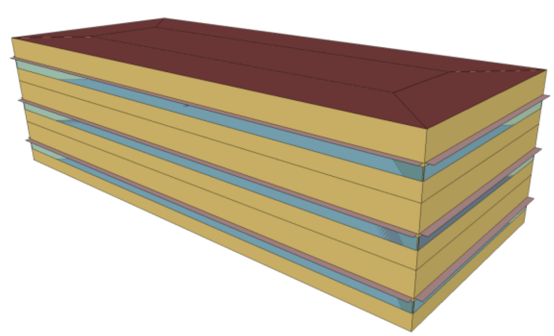
Benefits and Costs of Energy Standard Adoption in New Commercial Buildings: National Summary

Joshua Kneifel





BIRDS
Building Industry Reporting and Design *for* Sustainability

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

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Benefits and Costs of Energy Standard Adoption in New Commercial Buildings: National Summary

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Abstract

Energy efficiency requirements in energy codes for commercial buildings vary across states, and many states have not yet adopted the latest energy efficiency standard edition. As of December 2011, states had adopted energy codes ranging across editions of *American Society of Heating, Refrigerating and Air-Conditioning Engineers Energy Standard for Buildings Except Low-Rise Residential Buildings (ASHRAE) 90.1* (*-2001*, *-2004*, and *-2007*). Some states do not have a code requirement for energy efficiency, leaving it up to the locality or jurisdiction to set its own requirements. This study considers the impacts that the adoption of newer, more stringent energy codes for commercial buildings would have on building energy use, operational energy costs, building life-cycle costs, and cradle-to-grave energy-related carbon emissions.

The results of this report are based on analysis of the Building Industry Reporting and Design for Sustainability (BIRDS) database, which includes 12 540 whole building energy simulations covering 11 building types in 228 cities across all U.S. states for 9 study period lengths. The performance of buildings designed to meet current state energy codes is compared to their performance when meeting new editions of *ASHRAE 90.1-2007* design requirements to determine whether more stringent energy standard editions are cost-effective in reducing energy consumption and energy-related carbon emissions. Each state energy code is also compared to a “Low Energy Case” (LEC) building design based on *ASHRAE 189.1-2009*, which increases energy efficiency beyond the *ASHRAE 90.1-2007* design. The estimated savings for each of the building types are aggregated using state-level new commercial building construction data to calculate the magnitude of the incremental savings that a state may realize if it were to adopt a more energy efficient standard as its state energy code. These state-level estimates are further aggregated to the national level to estimate the potential total impact from nationwide adoption of more stringent energy codes.

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 (EL) at the National Institute of Standards and Technology (NIST). The study is designed to assess the energy use, life-cycle cost, and energy-related carbon emissions impacts from the adoption of new state energy codes based on more stringent building energy standard editions. The intended audience is researchers and policy makers in the commercial building sector, and others interested in building energy efficiency.

Disclaimers

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.

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List of Acronyms

Acronym	Definition
AEO	Applied Economics Office
AIRR	Adjusted Internal Rate of Return
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BIRDS	Building Industry Reporting and Design for Sustainability
CBECS	Commercial Building Energy Consumption Survey
CH4	Methane
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent
DOE	Department of Energy
EEFG	EnergyPlus Example File Generator
eGRID	Emissions and Generation Resource Integrated Database
EIA	Energy Information Administration
EL	Engineering Laboaratory
EPA	Environmental Protection Agency
FEMP	Federal Energy Management Program
FERC	Federal Energy Regulatory Commission
HVAC	Heating, Ventilating, and Air Conditioning
I-P	Inch-Pounds (Customary Units)
IECC	International Energy Code Council
ISO	International Organization for Standardization
LCA	Life-Cycle Assessment
LCC	Life-Cycle Cost
LEC	Low Energy Case
MRR	Maintenance, Repair, and Replacement
N2O	Nitrous Oxide
NERC	North American Electric Reliability Corporation
NIST	National Institute of Standards and Technology
PNNL	Pacific Northwest National Laboratory
ROI	Return On Investment
S-I	System International (Metric Units)
SEER	Seasonal Energy Efficiency Ratio
SHGC	Solar Heat Gain Coefficient

Acronym	**Definition**
SPV	Single Present Value
UPV*	Uniform Present Value Modified for Fuel Price Escalation

Executive Summary

Energy efficiency requirements in energy codes for commercial buildings vary across states, and many states have not yet adopted the latest energy standard edition. As of December 2011, state energy code adoptions range across editions of the *American Society of Heating, Refrigerating and Air-Conditioning Engineers Energy Standard for Buildings Except Low-Rise Residential Buildings (ASHRAE 90.1-2001, -2004,* and *-2007*). Some states in the United 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, particularly those states that have not yet adopted an energy code, if they were to adopt more energy efficient commercial building energy standard editions.

The results of this report are based on analysis of all fifty states in the U.S. using the Building Industry Reporting and Design for Sustainability (BIRDS) database. BIRDS includes 12 540 whole-building energy simulation estimates covering 11 building types in 228 cities across all U.S. states for 9 study period lengths. The performance of buildings designed to meet current state energy codes is compared to their performance when meeting alternative building energy standard editions to determine whether more stringent energy standard editions are cost-effective in reducing energy use and energy-related carbon emissions. Each state energy code is also compared to a "Low Energy Case" (LEC) building design based on *ASHRAE 189.1-2009* (*Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings*), which increases energy efficiency beyond the *ASHRAE 90.1-2007* design.

Overall, adoption of *ASHRAE 90.1-2007* for the 19 states that have not yet adopted it as their state energy code leads to percentage reductions in energy use, energy costs, and energy-related carbon emissions. The average percentage reduction in energy use for new commercial buildings is 9.6 % while energy costs and carbon emissions realize average reductions of 12.2 % and 12.4 %, respectively for a 10-year study period. The reductions in energy use and carbon emissions are cost-effective, with average life-cycle costs decreasing by 0.7 %.

However, *ASHRAE 90.1-2007* does not lead to energy efficiency improvements over older editions of *ASHRAE 90.1* for all locations in the U.S. for two reasons. First, the simplification of the *ASHRAE* climate zones from 26 zones in *ASHRAE 90.1-2001* to eight zones in *ASHRAE 90.1-2004* resulted in the relaxation of some building envelope requirements for some locations. Second, *ASHRAE 90.1-2007* has less stringent solar heat gain coefficient (SHGC) requirements relative to *ASHRAE 90.1-2004* for some climate zones. As a result, high-rise, 100 % glazed buildings realize smaller reductions, and occasionally increases, in energy use because the less stringent window requirements overwhelm the stricter requirements for other energy efficiency measures analyzed in this study.

Overall, adoption of the LEC design in all 50 states leads to average nationwide percentage reductions in energy use, energy costs, and carbon emissions greater than those realized by *ASHRAE 90.1-2007*. The average reduction in energy use is 17.8 % over current state energy codes while energy costs and carbon emissions realize average reductions of 22.6 % and 20.4 %, respectively. The reductions in energy use and carbon emissions are cost-effective, with life-cycle costs decreasing by 1.1 % on average for a 10-year study period.

States with current energy codes based on older editions of *ASHRAE 90.1* realize greater percentage reductions in energy use, energy costs, and carbon emissions for the *ASHRAE 90.1-2007* design. For a small office building, the 13 states with reductions in energy use of at least 10 % have no state energy code or have adopted *ASHRAE 90.1-2001*. For the LEC design, 14 of the 18 states that realize reductions in energy use greater than 25 % have no state energy code or have adopted *ASHRAE 90.1-1999/2001*, including all 13 states with reductions greater than 30 %. Similar trends hold for energy costs and energy-related carbon emissions.

Over all building types, states located in the warmest climates realize the greatest reductions in energy use from adopting the "Low Energy Case" (LEC) design because several of the energy efficiency improvements (e.g., overhangs and daylighting controls) are more beneficial for warmer climates. However, states in colder climates see greater percentage reductions in energy costs and carbon emissions per percentage reduction in energy use because the energy efficiency measures tend to shift some energy use from electricity to natural gas consumption. Electricity is more expensive per unit of energy and typically has greater carbon dioxide equivalent (CO_2e) emissions per unit of energy relative to natural gas. Therefore the shift of energy consumption from electricity to natural gas can lead to greater reductions in energy costs and energy-related carbon emissions than reductions in total energy use. In an extreme case, cities located in Zone 8 realize a reduction in energy costs and carbon emissions while realizing an increase in total energy use.

The results for the *ASHRAE 90.1-2007* design have some similarities and some differences relative to the results for the LEC design. Similar to the LEC design, the current state energy codes are a key driver of variation in the results. The variation across climate zones diverges depending on the state energy code. For locations in states that have not adopted any state energy code or have adopted older editions of *ASHRAE 90.1* (*-2001*), warmer climate zones realize greater percentage reductions in energy use. For cities located in states that have adopted *ASHRAE 90.1-2004*, the percentage reductions in energy use do not follow the same trend. Instead the percentage changes are the greatest for cities in Zone 2 followed by Zone 7 and smallest for cities in Zone 1 and Zone 3.

Similar to the LEC design results, some cities realize a shift in energy use from electricity to natural gas, which decreases energy costs and carbon emissions by a greater percentage than the percentage decrease in energy consumption. However, when averaged across all cities in a climate zone, nearly all zones realize smaller percentage reductions in carbon emissions than the percentage reductions in energy use because adopting *ASHRAE 90.1-2007* decreases consumption of both electricity and natural gas for most cities.

The length of the study period impacts life-cycle cost-effectiveness to some degree. Assuming nationwide adoption of the LEC design, a 10-year study period realizes average life-cycle cost decreases of 1.1 % for all building types and locations. The percentage decrease in life-cycle costs is 1.4 % for a 20-year, 1.8 % for a 30-year, and 1.9 % for a 40-year study period. As the study period length increases from 5 years to 40 years, life-cycle cost-effectiveness tends to increase for more energy efficient commercial building designs.

By combining the amount of new floor area in a state with its average impacts, it is possible to estimate the magnitude of the impacts that nationwide adoption of a given building design would have at the state and national levels. States with the most newly constructed commercial building floor area tend to realize the greatest total energy use, energy cost, energy-related carbon emissions, and life-cycle cost reductions from adopting the *ASHRAE 90.1-2007* and LEC design even if those states do not realize the greatest percentage reductions. California, Florida, and Texas realize the greatest reductions in energy use (>1900 GWh) from adopting the LEC design. In comparison, states with the smallest amount of new floor area (Alaska, Delaware, Montana, Rhode Island, Vermont, and Wyoming) realize savings of less than 100 GWh from adopting the LEC design. For the 19 states that have not yet adopted the *ASHRAE 90.1-2007* design, Arizona realizes the greatest reductions in energy use (946 GWh) from doing so, while states with the smallest amount of new floor area (Alaska, Hawaii, Maine, North Dakota, South Dakota, and Wyoming) realize savings of less than 106 GWh. Similar trends occur for total energy cost reductions and energy-related carbon emissions savings.

The nationwide adoption of more efficient energy codes decreases total life-cycle costs. Adopting the LEC design decreases total life-cycle costs for 48 of 50 states for a 10-year study period, with Florida ($151.3 million), California ($124.9 million), and Texas ($106.8 million) realizing the greatest life-cycle cost savings. The two states that realize an increase in life-cycle costs are Oregon ($0.4 million) and Washington ($11.5 million). For a 10-year study period, adopting the *ASHRAE 90.1-2007* design reduces total life-cycle costs for 17 of 19 states, including 8 of 10 that have adopted *ASHRAE*

90.1-2001 or have not yet adopted a state energy code for commercial buildings. The greatest life-cycle cost savings are realized by Colorado ($53.9 million), Arizona ($30.8 million), and Alabama ($25.7 million). The two states that realize an increase in total life-cycle costs are Kansas ($2.9 million) and Oklahoma ($5.7 million).

The state-level impacts are aggregated to determine the total impact of nationwide adoption of both the *ASHRAE 90.1-2007* and LEC designs. Nationwide adoption of the LEC design leads to reductions totaling 34.4 TWh in energy consumption, $2.8 billion in energy costs, 26.3 million metric tons in energy-related carbon emissions, and $1.0 billion in life-cycle costs for a 10-year study period. Nationwide adoption of the *ASHRAE 90.1-2007* design leads to reductions totaling 4.9 TWh in energy consumption, $312 million in energy costs, 3.8 million metric tons in energy-related carbon emissions, and $173 million in life-cycle costs for a 10-year study period. An increase in the study period length increases the total savings for all four impacts because as the length of the study period increases, energy cost savings become a greater fraction of total life-cycle cost savings.

In general, the states that realize the greatest total reductions in energy use also realize the greatest reductions in energy costs and energy-related carbon emissions. However, states with higher average electricity prices and electricity emissions rates, and states that realize a greater shift of fuel consumption from electricity to natural gas, realize greater reductions in energy costs and carbon emissions holding energy use savings constant.

The changes per unit of floor area vary across Census regions, with the same trends holding for adoption of both the *ASHRAE 90.1-2007* and LEC designs. The Northeast realizes the greatest energy cost savings per unit energy use savings due to its higher average higher electricity price. The Midwest realizes the greatest carbon emissions savings per unit of energy use savings because its average electricity emissions rate is much higher than that of the other Census regions. The West realizes the greatest life-cycle cost savings per unit of floor area, which is a result of a number of factors, including the baseline energy codes for the cities located in the Census region, the regional average electricity price, average energy use savings, and local construction costs.

The incremental impacts in a state from adopting each newer edition of *ASHRAE 90.1* lead to some interesting conclusions. For the nine states that have no state energy code, adoption of *ASHRAE 90.1-2001* would lead to minimal energy use reductions (16 kWh/m^2) while significantly increasing total life-cycle costs ($15.39/m^2).[1] The reason for this result is that the primary changes in the standard from *ASHRAE 90.1-1999* to

[1] Excludes Arizona because three of the six cities in the BIRDS database have adopted *ASHRAE 90.1-2004* as their local energy code.

ASHRAE 90.1-2001 target the required efficiencies of HVAC equipment. The additional first costs of increasing the efficiency of HVAC equipment appear to be greater than the energy cost savings realized over the 10-year study period.

The adoption of *ASHRAE 90.1-2004* leads to significant incremental average reductions in energy use (112 kWh/m^2) while significantly decreasing total life-cycle costs ($15.52/$m^2$) relative to adopting *ASHRAE 90.1-2001*, and entirely offsets the incremental increase in life-cycle costs from adopting *ASHRAE 90.1-2001* for five of the nine states with no state energy code. One state, Alaska, realizes an increase in energy use relative to *ASHRAE 90.1-2001*, which is a result of building requirements being relaxed for some cities due to the climate zone consolidation from *ASHRAE 90.1-2001* to *ASHRAE 90.1-2004*.

The adoption of *ASHRAE 90.1-2007* leads to significantly smaller average incremental reductions in energy use (71 kWh/m^2) and life-cycle costs ($3.04/$m^2$) relative to adopting *ASHRAE 90.1-2004*. Two of the nineteen states (Arkansas and Oklahoma) realize an increase in life-cycle costs relative to *ASHRAE 90.1-2004*.

The adoption of the LEC design leads to the greatest incremental impacts on total energy use (202 kWh/m^2), and similar incremental impacts on life-cycle costs ($4.24/$m^2$) as *ASHRAE 90.1-2007* for the nineteen states that have not yet adopted *ASHRAE 90.1-2007*. Only one of the nineteen states (West Virginia) realizes an increase in life-cycle costs relative to *ASHRAE 90.1-2007*.

This study is limited in scope and would be strengthened by including sensitivity analysis, expanding the BIRDS database, and enabling public access to all the results. The environmental assessment in the BIRDS database is currently being expanded beyond energy-related carbon emissions to cover building materials and a full range of cradle-to-grave life-cycle environmental impacts. Additional energy efficiency measures, fuel types, discount rates, and building types would also expand the scope of the database. Also, given that new buildings account for a small fraction of the entire building stock, incorporating analysis of energy retrofits to these same prototype buildings would increase the coverage of the database.

The extensive BIRDS database can be used to answer many more questions than posed in this report, and will be made available to the public through a simple-to-use software tool that allows others access to the database for their own research on building energy efficiency and sustainability. These improvements are underway, with comprehensive sustainability assessment and more detailed reporting and release of the BIRDS software scheduled for September 2013.

1 Introduction

1.1 Background

Energy efficiency requirements in current energy codes for commercial buildings vary across states, and many states have not yet adopted the latest energy efficiency standard editions. As of December 2011, state energy code adoptions range across editions of the *American Society of Heating, Refrigerating and Air-Conditioning Engineers Energy Standard for Buildings Except Low-Rise Residential Buildings (ASHRAE 90.1-2001*, *-2004*, and *-2007*). *ASHRAE Standard 90.1* is the industry consensus standard to establish the minimum energy-efficient requirements of buildings, other than low-rise residential buildings. 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 standard editions.

1.2 Literature Review

Pacific Northwest National Laboratory (2009) estimates the impacts for each state of adopting the most recent edition of the *ASHRAE 90.1* Standard as of 2009, *ASHRAE 90.1-2007*, as the commercial building energy code relative to the state's current energy code. For states without a state commercial building energy code, the baseline is assumed to be *ASHRAE 90.1-1999* because it is considered to represent common practice in the industry. The annual energy use savings and energy cost savings are estimated for three Department of Energy (DOE) benchmark buildings -- a medium-sized office building, a non-refrigerated warehouse, and a mid-rise apartment building -- to represent non-residential, semi-heated, and residential uses, respectively. The buildings are simulated in the *EnergyPlus* whole building energy software (DOE, 2009a) for 97 cities located across the U.S., ensuring that each climate zone in each state is represented. The study reports annual electricity and natural gas consumption per square foot of floor area for the buildings, assuming they are built to meet both the state's current code and *ASHRAE 90.1-2007*. Based on these results, the percentage savings in energy and energy costs are calculated for the three building types for each state. The study does not compare energy use and energy costs across states. Life-cycle costs and carbon emissions are not considered in the study.

Kneifel (2010) creates a framework to simultaneously analyze the impacts of improving energy efficiency on energy use, energy costs, life-cycle costs, and carbon emissions through an integrated design context for new commercial buildings. The paper compares the savings of constructing 11 prototype commercial buildings to meet the building envelope requirements of *ASHRAE 90.1-2007* and a "Low Energy Case," relative to *ASHRAE 90.1-2004*, for 16 cities in different climate zones across the contiguous United

States. The paper finds minimal improvements in energy efficiency from building to meet *ASHRAE 90.1-2007* relative to *ASHRAE 90.1-2004* while significant savings is found by building to meet the “Low Energy Case.” The “Low Energy Case” is often cost-effective on a first cost basis and is always cost-effective over the longer study period lengths.

Kneifel (2011a) expands on the framework and analysis in Kneifel (2010) by analyzing the impact of adopting the building envelope requirements of *ASHRAE 90.1-2007* and a “Low Energy Case” relative to *ASHRAE 90.1-2004* in terms of energy use, energy costs, energy-related carbon emissions, and life-cycle costs for 228 cities across the U.S. with at least one city in each state. Analysis includes 4 study period lengths (1, 10, 25, and 40 years). The paper finds that, on average, the more energy efficient building designs are cost-effective. However, there is significant variation across states in terms of energy use savings and life-cycle cost-effectiveness driven by both climate and construction costs. There is also significant variation across cities within a state, even cities located within the same climate zone. These variations are a result of differences in local material and labor costs as well as energy costs.

Kneifel (2013) analyzes 12 540 whole-building energy simulations in the Building Industry Reporting and Design for Sustainability (BIRDS) database covering 11 building types in 228 cities across all U.S. states for 9 study period lengths (1, 5, 10, 15, 20, 25, 30, 35, and 40 years). Current state energy code performance is compared to the performance of alternative *ASHRAE 90.1 Standard* editions to determine whether more stringent energy standard editions are cost-effective in reducing energy consumption and energy-related carbon emissions. This analysis includes a “Low Energy Case” (LEC) building design based on *ASHRAE 189.1-2009*, which increases energy efficiency beyond the *ASHRAE 90.1-2007* design. Results are analyzed in detail for the *ASHRAE 90.1-2007* and LEC designs. Results are aggregated at the state level for seven states, Alaska, Colorado, Florida, Maryland, Oregon, Tennessee, and Wisconsin, 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 stringent state energy code for commercial buildings.

Kneifel (2013b), Kneifel (2013c), Kneifel (2013d), and Kneifel (2013e) implement the analysis approach developed in Kneifel (2013a) for an individual state and analyze each state in the Northeast, Midwest, South, and West Census Regions, respectively. The results for each state, both on a percentage and aggregate basis, are compared across the Census Region to determine the driving factors for variation across states in the relative impacts of adopting more stringent state energy codes. The results are aggregated to the Census Region level to estimate the total region-wide impacts.

1.3 Purpose

The purpose of this study is to analyze the results from the BIRDS database reported in Kneifel (2013a, 2013b, 2013c, 2013d, 2013e), and summarize the results into the key nationwide trends and important interpretations for energy efficiency in new commercial buildings. The performance of buildings designed to meet current state energy codes is compared to their performance when meeting newer editions of *ASHRAE 90.1* requirements to determine whether more stringent energy standard editions are cost-effective in reducing energy consumption and energy-related carbon emissions. Each state energy code is also compared to a "Low Energy Case" (LEC) building design based on *ASHRAE 189.1-2009*, which increases energy efficiency beyond the *ASHRAE 90.1-2007* design. The estimated savings for each of the building types are aggregated using new commercial building construction data to calculate the magnitude of the incremental savings that the nation may realize if its states were to adopt more energy efficient standard editions.

1.4 Approach

This study uses the Building Industry Reporting and Design for Sustainability (BIRDS) database to analyze the benefits and costs of increasing building energy efficiency across the United States. BIRDS is a compilation of whole building energy simulations, building construction cost data, maintenance, repair, and replacement rates and costs, and energy-related carbon emissions data for 11 building types in 228 cities across all U.S. states. The analysis compares energy performance of buildings designed to each state's current energy code for commercial buildings to the performance of more energy efficient building designs to determine the energy use savings, energy cost savings, and energy-related carbon emissions reductions, and the associated life-cycle costs, resulting from adopting stricter standards as the state's energy code.

Results are analyzed both in percentage and total value terms. The percentage savings results allow for direct comparisons across energy standard editions, building types, study period lengths, climate zones, and cities both within each state and across the nation. Results are aggregated to the state and national levels to estimate the magnitude of total energy use savings, energy cost savings, and energy-related carbon emissions reductions that could be attained by adoption of more stringent energy codes, and the associated total life-cycle costs.

Results are summarized using both tables and figures. In cases where the material being discussed is of secondary importance, the associated table or figure is placed in the Appendices. The order in which tables and figures appear in the Appendices corresponds to the order in which they are cited in the text.

2 Study Design

The BIRDS database used in this study was built following the framework developed in Kneifel (2010) and further expanded in Kneifel (2011a) and Kneifel (2013). This study analyzes whole building energy simulations, life-cycle costs, and energy-related carbon emissions for 5 energy efficiency designs for 11 building types, 228 cities across all fifty states, and 9 study period lengths.[2]

2.1 Building Types

The building characteristics in Table 2-1 describe the 11 building types used in this study, which include 2 dormitories, 2 apartment buildings, a hotel, 3 office buildings, a school, a retail store, and a restaurant. The building types were selected based on a combination of factors, including fraction of building stock represented, variation in building characteristics, and ease of simulation design. These building types represent 46 % of the existing U.S. commercial building stock floor space.[3] The prototype buildings range in size from 465 m^2 (5000 ft^2) to 41 806 m^2 (450 000 ft^2). The building abbreviations defined in Table 2-1 are used to represent the building types in tables throughout this study.

Table 2-1 Building Characteristics

Building Type	Bldg. Abbr.	Floors	Floor Height m (ft)	Wall	Roof†	Pct. Glazing	Building Size m^2 (ft^2)	Occupancy Type	U.S. Floor Space (%)
Dormitory	DORMI04	4	3.66 (12)	Mass	IEAD	20 %	3097 (33 333)	Lodging	7.1 %
Dormitory	DORMI06	6	3.66 (12)	Steel	IEAD	20 %	7897 (85 000)		
Hotel	HOTEL15	15	3.05 (10)	Steel	IEAD	100 %	41 806 (450 000)		
Apartment	APART04	4	3.05 (10)	Mass	IEAD	12 %	2787 (30 000)		
Apartment	APART06	6	3.15 (10)	Steel	IEAD	14 %	5574 (60 000)		
School, High	HIGHS02	2	4.57 (15)	Mass	IEAD	25 %	12 077 (130 000)	Education	13.8 %
Office	OFFIC03	3	3.66 (12)	Mass	IEAD	20 %	1858 (20 000)	Office	17.0 %
Office	OFFIC08	8	3.66 (12)	Mass	IEAD	20 %	7432 (80 000)		
Office	OFFIC16	16	3.05 (10)	Steel	IEAD	100 %	24 155 (260 000)		
Retail Store	RETAIL1	1	4.27 (14)	Mass	IEAD	10 %	743 (8000)	Mercantile*	6.0 %
Restaurant	RSTRNT1	1	3.66 (12)	Wood	IEAD	30 %	465 (5000)	Food Service	2.3 %

*Only includes non-mall floor area.
†IEAD = Insulation Entirely Above Deck

[2] See Kneifel (2011b) for additional details on the whole building energy simulations used in the BIRDS database.

[3] Estimate is based on the Commercial Building Energy Consumption Survey (CBECS) database.

2.2 Building Designs

Current state energy codes are based on different editions of the *International Energy Conservation Code (IECC)* or *ASHRAE 90.1 Standard*, which have requirements that vary based on a building's characteristics and the climate zone of the building location. For this study, the prescriptive requirements of the *ASHRAE 90.1 Standard*-equivalent design 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. A "Low Energy Case" design based on *ASHRAE 189.1-2009,* which goes beyond *ASHRAE 90.1-2007,* is included as an additional building design alternative.

Table 2-2 shows that commercial building energy codes as of December 2011 vary by state.[4] In a few instances, local jurisdictions have adopted energy standard editions that are more stringent than the state energy codes.[5] These cities are also included in Table 2-2.

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[4] Since the publication of Kneifel (2011b) and Kneifel (2012), the BIRDS database has been updated to include subsequent changes in state energy codes through December 2011.

[5] Local and jurisdictional requirements are obtained from the Database of State Incentives for Renewables and Efficiency (DSIRE). State energy code requirements targeting only public buildings and green standards are ignored in this study.

Table 2-2 Energy Code by State and City Exception

Location	Energy Code	Location	Energy Code	Location	Energy Code
AK	**None**	**IN**	**2007**	**NV**	**2004**
AL	**None**	**KS**	**None**	**NY**	**2007**
Huntsville	2001	**KY**	**2007**	**OH**	**2007**
AR	**2001**	**LA**	**2007**	**OK**	**None**
AZ	**None**	**MA**	**2007**	**OR**	**2007**
Flagstaff	2004	**MD**	**2007**	**PA**	**2007**
Phoenix	2004	**ME**	**None**	**RI**	**2007**
Tucson	2004	**MI**	**2007**	**SC**	**2004**
CA*	**2007**	**MN**	**2004**	**SD**	**None**
CO	**2001**	**MO**	**None**	Huron	2001
Grand Junction	2004	St Louis	2001	**TN**	**2004**
CT	**2007**	**MS**	**None**	**TX**	**2007**
DE	**2007**	**MT**	**2007**	**UT**	**2007**
FL	**2007**	**NC**	**2007**	**VA**	**2007**
GA	**2007**	**ND**	**None**	**VT**	**2007**
HI	**2004**	**NE**	**2007**	**WA**	**2007**
IA	**2007**	**NH**	**2007**	**WI**	**2007**
ID	**2007**	**NJ**	**2007**	**WV**	**2001**
IL	**2007**	**NM**	**2007**	**WY**	**None**

Note: Some city ordinances require energy codes that exceed state energy codes.
Note: State codes as of December 1, 2011.
Note: *ASHRAE 90.1-2007* is the building design that best matches Title 24 requirements.

State energy codes vary from *ASHRAE 90.1-1999* to *ASHRAE 90.1-2007* with some regional trends shown in Figure 2-1. The states in the central U.S. tend to wait longer to adopt newer *ASHRAE 90.1 Standard* editions. However, there are many cases in which energy codes of neighboring states vary drastically. For example, Missouri has no state energy code while of the 8 surrounding states, 2 have no state energy code, 1 has adopted *ASHRAE 90.1-2001*, 1 has adopted *ASHRAE 90.1-2004*, and 4 have adopted *ASHRAE 90.1-2007*.

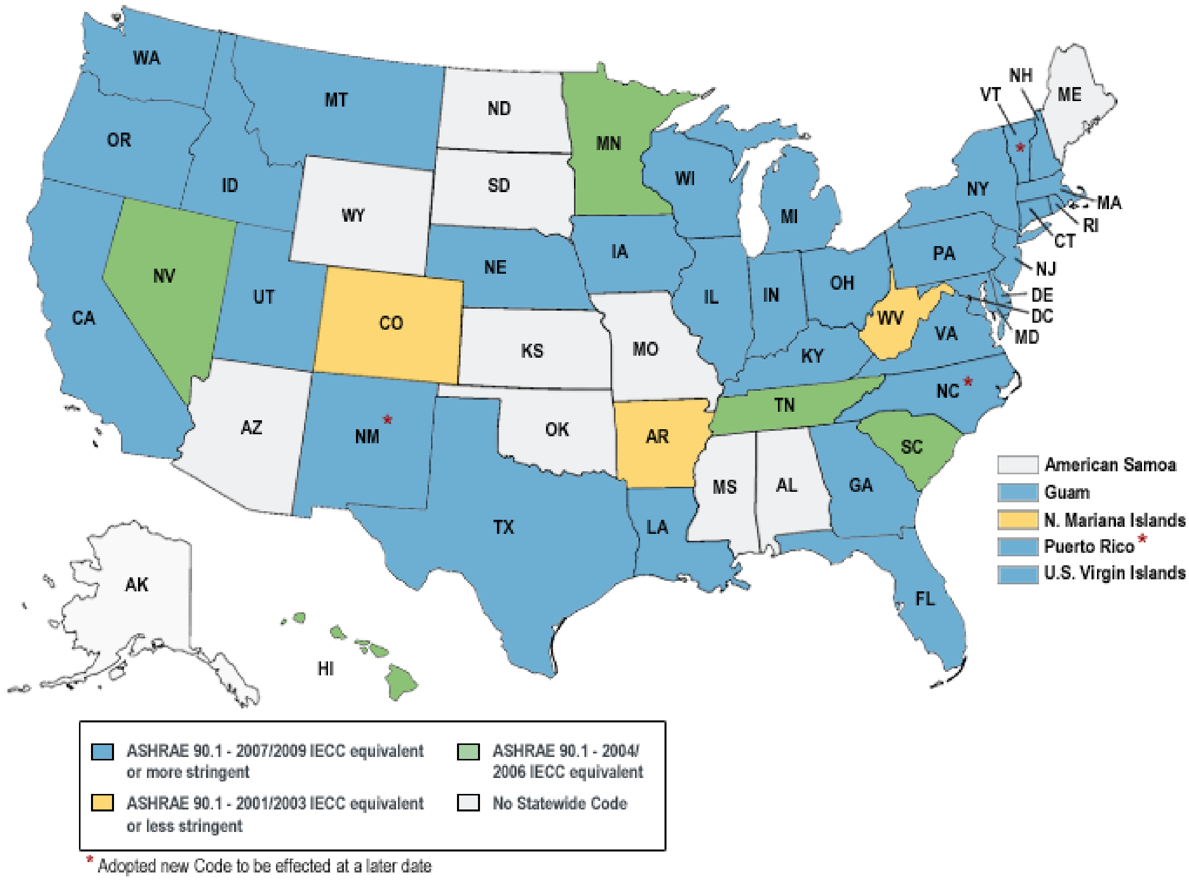

Figure 2-1 State Commercial Energy Codes[6]

The 228 cities and *ASHRAE* climate zones for the U.S. are seen in Figure 2-2. These cities are selected for three reasons. First, the cities are spread out to represent the entire United States, and represent as many climate zones as possible in each state. Second, the locations include all the major population centers in the country. Third, multiple locations for a climate zone within a state are included to allow building costs to vary for each building design.

[6] Figure was obtained from the DOE Building Technologies Program in December 2011.

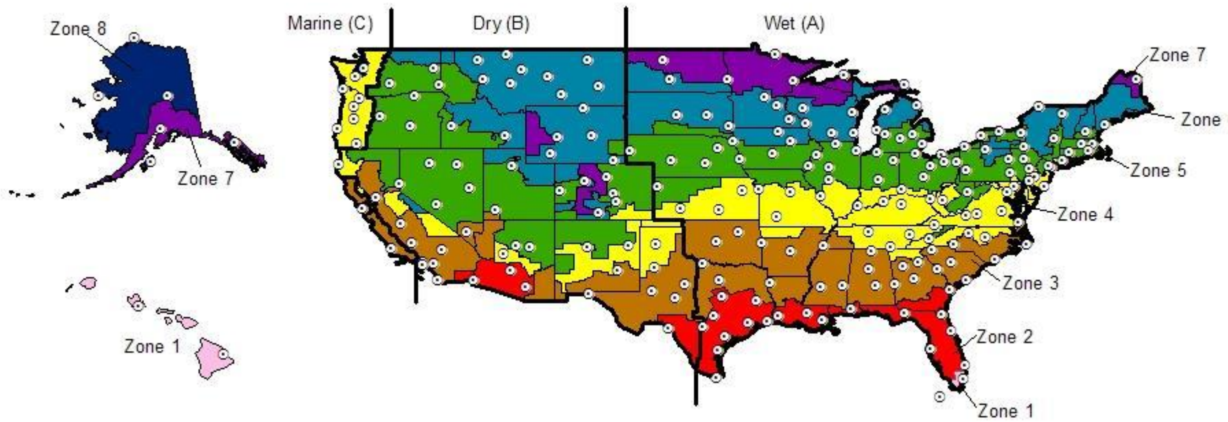

Figure 2-2 Cities and ASHRAE Climate Zones

2.3 Study Period Lengths

Nine study period lengths are chosen for this analysis: 1 year, 5 years, 10 years, 15 years, 20 years, 25 years, 30 years, 35 years, and 40 years. The wide variation in investment time horizons allows this report to analyze the impact the study period length has on the benefits and costs of more stringent state energy code adoption. A 1-year study period is more representative of a developer that intends to sell a property soon after it is constructed. A 5-year to 15-year study period more closely represents a building owner's time horizon because few owners are concerned about costs realized beyond a decade into the future. The 20-year to 40-year study periods better represents institutions, such as colleges or government agencies, because these entities will own or lease buildings for 20 or more years. Most of the analysis in this study uses a 10-year study period.

3 Cost Data

The cost data collected to estimate life-cycle costs for the BIRDS database originates from multiple sources, including RS Means databases (RS Means, 2009), Whitestone (2008), and the U.S. Energy Information Administration (EIA) (EIA, 2010).[7] Costs are grouped into two categories, first costs that include initial building construction costs and future costs that include operational costs, maintenance, repair, and replacement costs, and building residual value. Both of these cost categories are described below.

3.1 First Costs

Building construction costs are obtained from the RS Means *CostWorks* online databases (RS Means, 2009). The costs of a prototypical building are estimated by the RS Means *CostWorks Square Foot Estimator* to obtain the default costs of each component within each separate building building type. The RS Means default building is the baseline used to create a building that is compliant with each of the five energy efficiency design alternatives: *ASHRAE 90.1-1999*, *ASHRAE 90.1-2001*, *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, and the higher efficiency "Low Energy Case" (LEC) design. The RS Means default buildings are adapted to match the five prototype building designs by using the RS Means *CostWorks Cost Books* databases.

Five components -- roof insulation, wall insulation, windows, lighting, and HVAC efficiency -- are changed to make the prototypical designs *ASHRAE 90.1-1999, -2001, -2004,* and *-2007* compliant. A summary of the minimum requirement ranges, excluding HVAC efficiency, for each building design are shown in Table 3-1. The windows are selected to meet the minimum window characteristics (U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT)) required by the building design at the lowest possible cost. The lighting density in watts per unit of conditioned floor area is adjusted to meet each standard edition's requirements.

[7] See Kneifel (2012) for additional details of the cost data used in the BIRDS database.

Table 3-1 Energy Efficiency Component Requirements for Alternative Building Designs

Design Component	Parameter	Units	ASHRAE 90.1-1999	ASHRAE 90.1-2001	ASHRAE 90.1-2004	ASHRAE 90.1-2007	Low Energy Case*
Roof Insulation	R-Value	m^2·K/W (ft^2·°F·h/Btu)	1.7 to 4.4 (10.0 to 25.0)	1.7 to 4.4 (10.0 to 25.0)	2.6 to 3.5 (15.0 to 20.0)	2.6 to 3.5 (15.0 to 20.0)	4.4 to 6.2 (25.0 to 35.0)
Wall Insulation	R-Value	m^2*K/W (ft^2·°F·h/Btu)	0.0 to 3.8 (0.0 to 21.6)	0.0 to 3.8 (0.0 to 21.6)	0.0 to 2.7 (0.0 to 15.2)	0.0 to 2.7 (0.0 to 15.2)	0.7 to 5.5 (3.8 to 31.3)
Windows	U-Factor	W/(m2·K) (Btu/(h·ft^2·°F))	1.42 to 7.21 (0.25 to 1.27)	1.42 to 7.21 (0.25 to 1.27)	1.99 to 6.47 (0.35 to 1.14)	2.50 to 6.47 (0.44 to 1.14)	1.97 to 6.42 (0.35 to 1.13)
	SHGC	Fraction	0.14 to NR†	0.14 to NR†	0.17 to NR†	0.25 to NR	0.25 to 0.47
Lighting	Power Density	W/m^2 (W/ft^2)	14.0 to 20.5 (1.3 to 1.9)	14.0 to 20.5 (1.3 to 1.9)	10.8 to 16.1 (1.0 to 1.5)	10.8 to 16.1 (1.0 to 1.5)	8.6 to 16.1 (0.8 to 1.5)
Overhangs			None	None	None	None	Zones 1 to 5
Daylighting			None	None	None	None	Zones 1 to 8

†North facing SHGC requirements are less restrictive than the requirements for the other 3 orientations.
* Low Energy Case design requirements are taken from the EnergyPlus simulations, and are based on *ASHRAE 189.1-2009*.
NR = No Requirement for one or more climate zones. By definition, the value of SHGC cannot exceed 1.0.

The LEC design increases the thermal efficiency of insulation and windows beyond *ASHRAE 90.1-2007*, further reduces the lighting power density, and adds daylighting and window overhangs. The lighting density of the lighting system is decreased by first increasing the efficiency of the lighting system and then decreasing the number of fixtures in the lighting system.[8] Daylighting is included for all building types and climate zones. Overhangs are placed on the east, west, and south sides of the building for each floor in Climate Zone 1 through Climate Zone 5 because these warmer climates are the zones that benefit from blocking solar radiation.[9]

Since the design of the BIRDS database, *ASHRAE 90.1-2010* has been finalized and published. Table 3-2 gives a perspective of how the *ASHRAE 90.1-2007* and LEC designs compare to *ASHRAE 90.1-2010*. In general, the requirements for *ASHRAE 90.1-2010* are stricter than *ASHRAE 90.1-2007* and less strict than the LEC design. The key exception is the lighting power density requirements for mid-rise and high-rise residential buildings, and wall insulation requirements for steel-framed mid-rise and high-rise residential buildings, where the requirements for *ASHRAE 90.1-2010* are more stringent than for the LEC design.

[8] First, incandescent lighting is replaced with compact fluorescent lighting while typical T-12 fluorescent tube lighting is replaced with more efficient T-8 fluorescent tube lighting to decrease the lighting density of the lighting system. Second, the number of fixtures is reduced to meet the remainder of the required reduction in watts per unit of floor area. Increasing the efficiency of the lighting increases the costs of construction. The first approach increases first costs while the second approach decreases first costs for the lighting system. This approach is based on Belzer et al. (2005) and Halverson et al. (2006).
[9] Overhang cost source is Winiarski et al. (2003)

Table 3-2 Energy Efficiency Component Requirements for the *ASHRAE 90.1-2007*, *ASHRAE 90.1-2010*, and LEC Designs

Design Component	Parameter	Units	ASHRAE 90.1-2007	ASHRAE 90.1-2010	Low Energy Case*
Roof Insulation	R-Value	m^2·K/W (ft^2·°F·h/Btu)	2.6 to 3.5 (15.0 to 20.0)	2.6 to 3.5 (15.0 to 20.0)	4.4 to 6.2 (25.0 to 35.0)
Wall Insulation	R-Value	m^2*K/W (ft^2·°F·h/Btu)	0.0 to 2.7 (0.0 to 15.2)	0.0 to 2.7 (0.0 to 25.0)	0.7 to 5.5 (3.8 to 31.3)
Windows	U-Factor	W/(m2·K) (Btu/(h·ft^2·°F))	2.50 to 6.47 (0.44 to 1.14)	1.99 to 6.47 (0.35 to 1.2)	1.97 to 6.42 (0.35 to 1.13)
	SHGC	Fraction	0.25 to NR	0.25 to NR†	0.25 to 0.47
Lighting	Power Density	W/m^2 (W/ft^2)	10.8 to 16.1 (1.0 to 1.5)	6.5 to 15.1 (0.6 to 1.4)	8.6 to 16.1 (0.8 to 1.5)
Overhangs			None	None	Zones 1 to 5
Daylighting			None	Zones 1 to 8	Zones 1 to 8

* Low Energy Case design requirements are taken from the EnergyPlus simulations, and are based on *ASHRAE 189.1-2009*.
NR = No Requirement for one or more climate zones. By definition, the value of SHGC cannot exceed 1.0.

Table 3-3 summarizes the HVAC efficiency requirements for each building design option across the different types of HVAC equipment.[10] Note that the LEC design assumes the same efficiency as *ASHRAE 90.1-2007*. This study assumes that cooling equipment is run on electricity while heating equipment is run on natural gas. The most significant increases in HVAC 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 90.1 Standard* editions.

Table 3-3 HVAC Energy Efficiency Requirements for Alternative Building Designs

HVAC Type	Equipment Type	Unit	ASHRAE 90.1-1999	ASHRAE 90.1-2001	ASHRAE 90.1-2004	ASHRAE 90.1-2007	Low Energy Case
Cooling	Rooftop Packaged Unit	EER	8.2 to 9.0	9.0 to 9.9	9.2 to 10.1	9.5 to 13.0	9.5 to 13.0
	Air-Cooled Chiller	COP	2.5 to 2.7	2.8	2.8	2.8	2.8
	Water-Cooled Chiller	COP	3.80 to 5.20	4.45 to 5.50	4.45 to 5.50	4.45 to 5.50	4.45 to 5.50
	Split System with Condensing Unit	EER	8.7 to 9.9	9.9 to 10.1	10.1	10.1	10.1
Heating	Hot Water Boiler	E_t	75% to 80%	75% to 80%	75% to 80%	75% to 80%	75% to 80%
	Furnace	E_t	80%	75% to 80%	75% to 80%	75% to 80%	75% to 80%

Assume that 80 %E_c = 75% E_t and AFUE = E_t, where E_c = combustion efficiency; E_t = thermal efficiency; AFUE = Annual Fuel Utilization Efficiency
EER = Energy Efficiency Ratio
COP = Coefficient of Performance
Note: Efficiency requirement ranges are based on the system sizes calculated in the whole building energy simulations.

[10] This study does not account for new HVAC efficiency requirements set by federal regulations.

The HVAC system size varies across the five building designs because changing the thermal characteristics of the building envelope alters the heating and cooling loads of the building. The *EnergyPlus* whole building energy simulations "autosize" the HVAC system to determine the appropriate system size to efficiently maintain the thermal comfort while dealing with ventilation requirements. For each building design, the HVAC cost for the default HVAC system is replaced with the cost of the "autosized" HVAC system. An HVAC efficiency cost multiplier is used to adjust the HVAC costs in accordance with the standard efficiency requirements shown in Table 3-3.

Construction costs for a building in each location are estimated by summing the baseline costs for the RS Means default building and the changes in costs required to meet the alternative prototype designs. National average construction costs are adjusted with the 2009 RS Means *CostWorks City Indexes* to control for local material and labor price variations. The "weighted average" city construction cost index is used to adjust the costs for the baseline default building while "component" city indexes are used to adjust the costs for the design changes. Once the indexed construction cost of the building is calculated, it is multiplied by the contractor "mark-up" rate, 25 %, and architectural fees rate, 7 %, to estimate the building's "first costs" of construction for the prototype buildings. These rates are the default values used by the RSMeans *Square Foot Estimator*.

3.2 Future Costs

Component and building lifetimes and component repair requirements are based on data from Whitestone (2008). Building service lifetimes are assumed constant across climate zones: apartment buildings lasting for 65 years; dormitories for 44 years; and hotels, schools, office buildings, retail stores, and restaurants for 41 years.

Building component maintenance, repair, and replacement (MRR) rates are from Kneifel (2010) and Kneifel (2011a). Insulation and windows are assumed to have a lifespan greater than 40 years and have no maintenance requirements. Insulation is assumed to have no repair costs. Windows have an assumed annual repair cost equal to replacing 1 % of all window panes, with costs that vary depending on the required window specifications (RS Means, 2009). The heating and cooling units have different lifespans and repair rates based on climate, ranging from 4 years to 33 years for repairs and 13 years to 50 years for replacements.

MRR cost data are collected from two sources. The total maintenance and repair costs per square foot of conditioned floor area (minus the HVAC maintenance and repair costs) represent the baseline MRR costs per unit of floor area, which occur for a building type regardless of the energy efficiency measures incorporated into the design. These data are collected from Whitestone (2008), which reports average maintenance and repair costs per unit of floor area by building component for each year of service life for each building type. The building types in Whitestone do not match exactly to the 11 building types selected for this study, so the most comparable profile is selected.

RS Means *CostWorks* is the source of MRR costs for the individual components for which MRR costs change across alternative building designs, which in this analysis are the HVAC system, lighting system, and windows. Lighting systems, including daylighting controls for the LEC design, are assumed to be replaced every 20 years. The HVAC system size varies based on the thermal performance of the alternative building design, which results in varying MRR costs because smaller systems are relatively cheaper to maintain, repair, and replace.

Future MRR costs are discounted to equivalent present values using the Single Present Value (SPV) factors for future non-fuel costs reported in Rushing and Lippiatt (2008), which are calculated using the U.S. Department of Energy's 2008 real discount rate for energy conservation projects (3 %).

A building's residual value is its value at the end of the study period. It is estimated in three parts, for the building (excluding components replaced during the study period), the HVAC system, and the lighting system based on the approach defined in Fuller et al. (1996). The building's residual value is assumed to be equal to the building's first cost (minus any components replaced over the study period) multiplied by the ratio of the study period to the service life of the building, and discounted from the end of the study period.

Two components may be replaced during the study period, the lighting and HVAC systems. Residual values for these components are computed for each location in a similar manner to the building residual value. The remaining “life” of the component is determined by taking its service life minus the number of years since its last installation, whether it occurred during building construction or replacement. The ratio of remaining life to service life is multiplied by the installed cost of the lighting and HVAC systems, and discounted from the end of the study period. The lighting system service life is 20 years while the HVAC system service life varies by location based on Towers et al. (2008).

Annual energy costs are estimated by multiplying annual electricity and natural gas use predicted by the whole building energy simulation by the average state retail commercial electricity and natural gas prices, respectively. Average state commercial electricity and natural gas prices for 2009 are collected from the Energy Information Administration (EIA) Electric Power Annual State Data Tables and Natural Gas Navigator, respectively. The electricity and natural gas prices are assumed to change over time according to EIA forecasts from 2009 to 2039. These forecasts are embodied in the Federal Energy

Management Program (FEMP) Uniform Present Value Discount Factors for energy price estimates (UPV*) reported in Rushing and Lippiatt (2009).[11] The UPV* values are used to discount future energy costs to equivalent present values. The discount factors vary by Census region, building sector, and fuel type.

[11] The escalation rates for years 31 to 40 are assumed to be the same as for year 30.

4 Building Stock Data

Aggregating the savings for newly constructed commercial buildings to the state and national levels requires new construction data for each building type within each state. This study uses the commercial building weighting factors reported in Jarnagin and Bandyopadhyay (2010) to estimate the total energy use savings, energy cost savings, life-cycle cost savings, and carbon emissions reduction resulting from adopting newer energy standard editions for each state. Jarnagin and Bandyopadhyay (2010) use two databases to generate the commercial building weighting factors: the 2003 Commercial Buildings Energy Consumption Survey (CBECS) and a McGraw-Hill construction dataset. The databases and the resulting weighting factors are described below.

4.1 Databases

The Commercial Buildings Energy Consumption Survey (CBECS) is a sample survey that collects information on the existing stock of U.S. commercial buildings. The sample includes 5215 buildings across the U.S. and 14 building type categories: education, food sales, food service, health care, lodging, mercantile, office, public assembly, public order and safety, religious worship, service, warehouse and storage, other, and vacant. Each category includes up to 12 subcategories as shown in Table A-1 in the Appendix A. The survey data do not report the age or specific location of the building to protect the confidentiality of the respondents.

The McGraw-Hill dataset includes data for all new commercial buildings and additions, over 254 000 records and 761.8 million m^2 (8.2 billion ft^2) of new construction, for 2003 through 2007. The data are more detailed than the CBECS data, and includes year of construction and location.

4.2 Weighting Factors

Jarnagin and Bandyopadhyay (2010) maps the more detailed McGraw-Hill dataset to the CBECS categories and subcategories shown in Table 4-1. The prototype commercial buildings analyzed in this study, shown in bold, represent 46.4 % of nationwide new commercial building stock square footage for 2003 through 2007. The McGraw-Hill dataset is aggregated at the CBECS category-level. For this study, a prototype building is assumed to represent its entire CBECS category, which implies the prototypes together represent 56.8 % of the new commercial building stock.

Table 4-1 New Commercial Building Construction (U.S., 2003 through 2007)

Building	Detail	Conditioned Floor Area 1000 m^2 (1000 ft^2)	Percentage in Category	Percentage of Total
Office	**Large**	**20 451 (220 134)**	**22.2 %**	**2.6 %**
Office	**Medium**	**37 170 (400 091)**	**40.4 %**	**4.8 %**
Office	**Small**	**34 468 (371 009)**	**37.4 %**	**4.5 %**
Retail		**93 762 (1 009 246)**		**12.2 %**
Strip Mall		34 847 (375 093)		4.5 %
School	Primary	30 697 (330 418)		4.0 %
School	**Secondary**	**63 686 (685 508)**		**8.3 %**
Hospital		21 194 (228 131)		2.8 %
Other Health Care		26 865 (289 171)		3.5 %
Restaurant	**Sit Down**	**4055 (43 650)**		**0.5 %**
Restaurant	Fast Food	3605 (38 809)		0.5 %
Hotel	**Large**	**30 432 (327 562)**		**0.4 %**
Hotel/Motel	Small	10 576 (113 837)		1.4 %
Warehouse		102 746 (1 105 951)		13.4 %
Apartment	**High-rise**	**55 114 (593 241)**	**55.1 %**	**7.2 %**
Apartment	**Mid-rise**	**44 997 (484 343)**	**44.9 %**	**5.9 %**
No Prototype		153 270 (1 649 785)		20.0 %
Total (2003-2007)		767 934 (8 265 977)		100.0 %

The types and floor area of buildings being constructed vary across states**.** Table A-2, Table A-3, and Table A-4 in the Appendix A report new building construction for 2003 through 2007 by building type and state, in total square meters, total square feet, and percentage terms, respectively. The data in Table A-2 are used to aggregate the total savings for the new construction in the CBECS categories represented by the prototype building analyzed in this study. Nine of the eleven prototype commercial buildings analyzed in this study are covered by data reported in Table 4-1. No data for dormitories are reported, which limits the ability to estimate statewide impacts for the two types of dormitories.

5 Analysis Approach

The analysis in this report compares benefits and costs of the status quo state energy codes to more stringent alternatives. The relative changes in energy use, energy costs, energy-related carbon emissions, and life-cycle costs use the current energy code for a state as the baseline and uses each *ASHRAE 90.1 Standard* edition that is newer than the standard required by the current state energy code as an alternative design. The results are considered on both a percentage change and an aggregate change basis.

5.1 Energy Use

The analysis uses each state's current energy code as the baseline energy efficiency design. For any state without a state energy code, *ASHRAE 90.1-1999* is assumed to be the baseline because it represents minimum energy-related industry practices. 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*.

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.

5.2 Life-Cycle Costing

Life-cycle costing (LCC) takes into account all relevant costs throughout the chosen study period, including construction costs, maintenance, repair, and replacement costs, energy costs, and residual values. A cost's present value (PV) is calculated by discounting its nominal value into today's dollars based on the year the cost occurs and the assumed discount rate. LCC of buildings typically compares the costs for a baseline building design to the costs for alternative, more energy-efficient building designs to determine if future operational savings justify higher initial investments.[12] For this study, the design based on any *ASHRAE 90.1 Standard* edition that is newer than the standard edition required by the current state energy code is compared to the baseline state energy code compliant design to determine the changes in life-cycle costs.

[12] All life-cycle cost calculations are based on ASTM Standards of Building Economics (2012).

Two metrics are used to analyze changes in life-cycle costs: net LCC savings and net LCC savings as a percentage of base case LCC. Net LCC savings is the difference between the base case and alternative design's LCCs.

5.3 Carbon Assessment

The BIRDS database expands on Kneifel (2011a) by conducting a life-cycle assessment (LCA) of energy-related greenhouse gas emissions, following guidance in the International Organization for Standardization (ISO) 14040 series of standards for LCA. The analysis quantifies the greenhouse gas emissions from electricity and natural gas use on a cradle-to-grave basis, including emissions from raw materials acquisition, materials processing, generation, transmission, distribution, use, and end-of-life.

The assessment of cradle-to-grave energy-related carbon emissions considers a number of greenhouse gases for two types of energy consumption, electricity and natural gas. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the most prevalent. While carbon emissions from natural gas use can be assessed on a national average basis, those from electricity use are highly dependent upon the fuel mixes of regional electricity grids. For this reason, electricity emissions are assessed at the state-level using North American Electric Reliability Corporation (NERC) sub-region level data.[13] The life-cycle data sets for natural gas production and combustion as well as for all fuel sources in the electricity grid come from the U.S. Life-Cycle Inventory (LCI) database (LCI, 2012). The state-level average emissions rates per GWh (MBtu) of electricity generated are obtained from the 2007 Emissions and Generation Resource Integrated Database (eGRID, 2007), which is a collection of data from the EIA, the Federal Energy Regulatory Commission (FERC), and the Environmental Protection Agency (EPA).[14] Table A-5 in the Appendix A shows variation in the emissions rates for the top three greenhouse gases by state, which results from differing fuel mixes used for electricity generation in a state.[15]

These greenhouse gas emissions are converted into a common unit of measure called carbon dioxide equivalents (CO_2e) using equivalency factors reported in Table 5-1, which represent the global warming potential (GWP) of one unit of greenhouse gas relative to that of the same amount of carbon dioxide. For example, one unit of methane has 25 times the GWP as the same amount of carbon dioxide, and nitrous oxide has 298 times the GWP as carbon dioxide. The aggregated CO_2e is calculated by taking the amount of

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[13] For states located in more than one NERC sub-region, a weighted average of emissions rates for the multiple sub-regions is implemented.

[14] Emissions rates are held constant over all study periods.

[15] While carbon assessment of building construction, maintenance, repair, and replacement is currently excluded from the analysis, it is currently under development and will be included in future versions of this work.

each flow multiplied by its CO_2e factor, and summing the resulting CO_2 equivalencies. The results are analyzed in metric tons of CO_2e emissions, and will be referred to as "carbon emissions" for the remainder of the report.

Table 5-1 Greenhouse Gas Global Warming Potentials

Environmental Flow	GWP (CO_2e)
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298
Ethane, 1,1-difluoro-, HFC-152a	124
Ethane, 1,1,1-trichloro-, HCFC-140	146
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	1430
Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	6130
Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	10 000
Ethane, hexafluoro-, HFC-116	12 200
Methane, bromo-, Halon 1001	5
Methane, bromochlorodifluoro-, Halon 1211	1890
Methane, bromotrifluoro-, Halon 1301	7140
Methane, chlorodifluoro-, HCFC-22	1810
Methane, dichloro-, HCC-30	9
Methane, dichlorodifluoro-, CFC-12	10 900
Methane, monochloro-, R-40	13
Methane, tetrachloro-, CFC-10	1400
Methane, tetrafluoro-, CFC-14	7390
Methane, trichlorofluoro-, CFC-11	4750
Methane, trifluoro-, HFC-23	14 800

5.4 Analysis Metrics

Three metrics are used to analyze the results: simple percentage changes, aggregate changes, and changes per unit of floor area. The average percentage energy use savings, energy cost savings, energy-related carbon emissions reductions, and life-cycle cost savings are calculated by taking the simple average of the percentage savings for each location-building type combination in the state or nation. The average of the percentage change is used instead of the average change in total values for the state or nation because that would in effect give greater weight to buildings or locations with greater total changes. The simple average approach used in this study weights each location-building type equally.

The estimated change in total energy use, energy costs, energy-related carbon emissions, and life-cycle costs for each of the building types is combined with new commercial building construction data to calculate the magnitude of the available total savings a state may realize if it were to adopt a more energy efficient standard as its state energy code using the following equation.

$$(1)\, I_j = \frac{\sum_{i=1}^{11} CFA_{ji} * R_{ji}}{\sum_{i=1}^{11} F_{ji}}$$

Where I_j = total change for state *j*
CFA_i = average annual newly constructed floor area for building type *i* for state *j*
R_i = average change per unit of floor area for building type *i* for state *j*
F_i = fraction of average annual new floor area represented by building type *i* for state *j*

For each building type *i*, the average change per unit of floor area for all cities in a state (R_i) is multiplied by the average annual floor area of new construction for 2003 to 2007 for building type *i* in that state (CFA_i) to estimate the total savings for that building type for that state. The impacts are summed across all eleven building prototypes. These impacts are then divided by the amount of average annual new commercial floor area represented by the eleven building prototypes (*F*), which scale the results to the statewide impacts of all new commercial construction (I_j). Using this approach to estimate the total impacts for a state requires the assumption that the savings realized by the BIRDS building prototypes are representative of new commercial building construction as a whole.

The national-level impacts (I_T) are estimated using Equation 2, where the impacts for state *j* estimated using Equation 1 (I_j) are summed across all fifty states.

$$(2)\, I_T = \sum_{j=1}^{50} (I_j)$$

Where I_T = nationwide total impacts
I_j = total impacts in state *j*

The third metric, change per unit of floor area, allows for comparisons across states to determine which states realize the greatest impacts per unit of construction. Equation 3 shows this calculation, where the total statewide impacts estimated in Equation 1 (I_j) are divided by the total average annual new floor area for all building types in a state ($TCFA_j$), creating a metaphorical "bang-for-your-buck" comparison across states.

$$(3)\, AVGI_j = \frac{I_j}{TCFA_j}$$

Where $AVGI_j$ = average impact per unit of new floor area in state *j*
I_j = total impacts in state *j*
$TCFA_j$ = total average annual new floor area for all building types in state *j*

It is necessary to assume a particular study period length to generate results. Although the annual energy use savings and energy-related carbon emissions reductions, both in percentage and total value terms, are assumed to be the same across study period lengths, the energy costs and life-cycle costs vary with the study period length because costs vary year-over-year. A 10-year study period is used for the majority of this analysis because it is the most realistic investor time frame of the 9 study period length options.

5.5 Regression Analysis

Determining the influence of some factors considered in this study requires a more statistically rigorous approach: regression analysis. Regression analysis is used to estimate the correlation between characteristics of a location and the impact the location realizes from adopting a more stringent energy code. This study applies an Ordinary Least Squares (OLS) model with dummy variables, also referred to as a Least Squares Dummy Variable (LSDV) Model, for the regression analysis.

6 Nationwide Impacts of Adopting Low Energy Case Design

This section analyzes benefits from nationwide adoption of the LEC design relative to the current collection of state energy codes. Benefits are evaluated across several dimensions: time, building type, geography (climate zone and state), and energy code. There are three metrics implemented to analyze the results: percentage changes, total changes, and changes per unit of floor area. Regression analysis is used to statistically estimate the drivers of variation in impacts across cities within the same state.

6.1 Percentage Changes

Average percentage change impacts from adopting the LEC design are estimated for energy use, energy costs, carbon emissions, and life-cycle costs. Impacts are evaluated across four dimensions: study period length, building type, climate zone, and state energy code.

6.1.1 Results by Study Period Length

It is important to consider how the study period length – representing the time horizon of the investor -- impacts energy use, energy costs, energy-related carbon emissions, and life-cycle costs. Nine study period lengths are analyzed: 1 year, 5 years, 10 years, 15 years, 20 years, 25 years, 30 years, 35 years, and 40 years.

The average reduction in energy use from adoption of the LEC design is constant over all study period lengths because energy efficiency is assumed to be constant over time. Table 6-1 shows that the national average reduction in energy use across all cities in the study ranges from -10.6 % to -30.7 %, depending on the building type, with an overall national average of -17.8 %.

Table 6-1 Nationwide Average Percentage Change in Energy Use from Adoption of the LEC Design by Building Type

Building Type	Percentage Change
APART04	-14.8
APART06	-15.6
DORMI04	-16.9
DORMI06	-15.2
HOTEL15	-13.9
HIGHS02	-10.6
OFFIC03	-23.0
OFFIC08	-21.5
OFFIC16	-15.3
RETAIL1	-18.9
RSTRNT1	-30.7
Average	**-17.8**

As shown in Table 6-2, reductions in energy costs vary slightly, in percentage terms, over increasing study period lengths. The national average reduction in energy costs across all location-building type combinations changes from -22.8 % for a 1-year study period to -22.3 % for a 40-year study period. The minor variation is a result of the escalation rates used to adjust future energy prices, which vary by Census Region. The national average reduction ranges from -17.4 % to -35.6 %, depending on the building type and study period.

Table 6-2 Nationwide Average Percentage Change in Energy Costs from Adoption of the LEC Design by Building Type and Study Period Length

Building Type	Study Period Length								
	1	5	10	15	20	25	30	35	40
APART04	-21.5	-21.3	-21.2	-21.1	-21.0	-21.0	-20.9	-20.8	-20.7
APART06	-23.2	-23.0	-22.9	-22.8	-22.7	-22.6	-22.5	-22.4	-22.4
DORMI04	-22.4	-22.3	-22.2	-22.1	-22.1	-22.0	-21.9	-21.9	-21.8
DORMI06	-22.7	-22.5	-22.4	-22.3	-22.2	-22.1	-22.0	-22.0	-21.9
HOTEL15	-19.8	-19.6	-19.6	-19.5	-19.4	-19.3	-19.3	-19.2	-19.2
HIGHS02	-18.3	-18.1	-18.0	-17.9	-17.8	-17.7	-17.6	-17.5	-17.4
OFFIC03	-25.3	-25.2	-25.2	-25.2	-25.2	-25.2	-25.1	-25.1	-25.1
OFFIC08	-22.8	-22.8	-22.8	-22.8	-22.8	-22.8	-22.7	-22.7	-22.7
OFFIC16	-18.4	-18.4	-18.3	-18.3	-18.3	-18.2	-18.2	-18.2	-18.1
RETAIL1	-20.9	-20.9	-20.9	-20.9	-20.8	-20.8	-20.8	-20.8	-20.8
RSTRNT1	-35.6	-35.5	-35.4	-35.3	-35.3	-35.2	-35.2	-35.1	-35.1
Average	**-22.8**	**-22.7**	**-22.6**	**-22.6**	**-22.5**	**-22.5**	**-22.4**	**-22.3**	**-22.3**

Since the national average reduction in energy use across all location-building type combinations is constant over all study periods, the average energy-related carbon emissions are also assumed constant at -22.9 %.[16] The national average reduction in carbon emissions ranges from -18.5 % to -35.6 % depending on the building type, as shown in Table 6-3.

[16] Electricity fuel mixes are assumed to be fixed over all study periods.

Table 6-3 Nationwide Average Percentage Change in Carbon Emissions from Adoption of the LEC Design by Building Type

Building Type	Percentage Change
APART04	-21.6
APART06	-23.3
DORMI04	-22.6
DORMI06	-22.8
HOTEL15	-20.0
HIGHS02	-18.5
OFFIC03	-25.3
OFFIC08	-22.8
OFFIC16	-18.5
RETAIL1	-21.0
RSTRNT1	-35.6
Average	**-22.9**

Table 6-4 shows that the nationwide average percentage change in life-cycle costs varies significantly over increasing study period lengths, with the average change across all location-building type combinations ranging from -3.8 % to -1.1 %.

Table 6-4 National Average Percentage Change in Life-Cycle Costs from Adoption of the LEC Design by Building Type and Study Period Length

Building Type	Study Period Length								
	1	5	10	15	20	25	30	35	40
APART04	-1.1	0.0	-0.1	-0.5	-0.4	-0.5	-0.7	-0.8	-0.7
APART06	-0.1	0.1	-0.2	-0.6	-0.6	-0.7	-0.9	-1.1	-1.0
DORMI04	-7.0	-1.6	-1.2	-1.5	-1.3	-1.4	-1.5	-1.6	-1.5
DORMI06	0.5	-0.3	-0.6	-1.1	-1.0	-1.2	-1.4	-1.6	-1.5
HOTEL15	1.4	0.3	-0.1	-0.6	-0.7	-1.0	-1.2	-1.4	-1.4
HIGHS02	-1.5	-1.2	-1.3	-1.6	-1.6	-1.8	-2.0	-2.2	-2.1
OFFIC03	-10.1	-2.7	-2.2	-2.4	-2.1	-2.3	-2.4	-2.6	-2.5
OFFIC08	-4.1	-2.2	-2.1	-2.5	-2.2	-2.4	-2.5	-2.7	-2.6
OFFIC16	2.1	0.8	0.3	-0.4	-0.4	-0.7	-1.0	-1.2	-1.2
RETAIL1	-9.1	-0.3	-0.1	-0.6	-0.3	-0.5	-0.8	-0.9	-0.8
RSTRNT1	-12.2	-5.2	-4.2	-5.0	-4.7	-5.0	-5.3	-5.4	-5.4
Average	**-3.8**	**-1.1**	**-1.1**	**-1.5**	**-1.4**	**-1.6**	**-1.8**	**-1.9**	**-1.9**

Figure 6-1 shows the graphical representation of the national average change in life-cycle costs by building type. For a 1-year study period, the average percentage change in life-cycle costs ranges from -12.2 % to 2.1 % depending on the building type. The significant variation is driven by the residual value of the building and its components. Since the study period is only one year, the residual values are almost as large as the first costs of building construction, amplifying even minor variations in life-cycle costs.

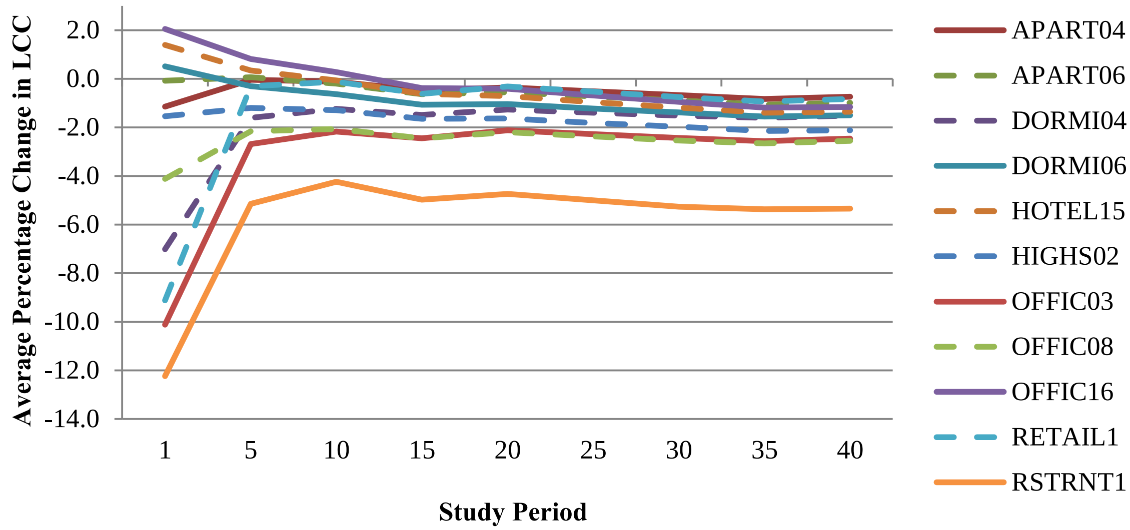

Figure 6-1 Nationwide Average Percentage Change in Life-cycle Costs from Nationwide Adoption of the LEC Design by Building Type and Study Period Length

From the 1-year to 10-year study period, there is a convergence towards zero followed by a slow but steady decrease from a 10-year to a 40-year study period. Building types that are not cost-effective for a 1-year study period slowly become cost-effective as the study period length increases. Building types that are cost-effective for a 1-year study period remain cost-effective for all longer study period lengths. All building types are cost-effective for study period lengths of 15 years or greater.

6.1.2 Results by Building Type

Table 6-5 shows the simple average changes by building type, in percentage terms, from adopting the LEC design for a 10-year study period. The restaurant realizes the greatest reductions while the high school realizes the smallest reductions in energy use, energy costs, and energy-related carbon emissions.

The occupant activity is the primary driver of the results for the high school, which is heavily occupied during the school year and lightly occupied during the summer months. Some of the energy efficiency measures decrease heat gains, which lead to lower cooling loads during warmer months and greater heating loads during the colder months. A significant portion of the reductions in electricity consumption during these colder months is offset by increases in natural gas consumption required to meet the increased heating loads. Thus, a greater portion of the high school's energy use occurs during the colder months relative to other building types. The combination of more energy use occurring during the colder months and the offsetting increase in natural gas consumption during those months leads to a smaller overall percentage reduction in energy use for high schools.

One of the reasons that the restaurant realizes the greatest reductions in energy use is that the restaurant has the smallest plug and process loads in terms of watts per unit of floor area. Since the plug and process load is the only electricity use not impacted by the energy efficiency measures adopted in this study, a greater fraction of energy use can be decreased for restaurants relative to the other building types.

The restaurant realizes the greatest life-cycle cost savings while the 16-story office building is the only building to realize an increase in life-cycle costs, on average. Overall, all buildings realize significant reductions in energy use, energy costs, and carbon emissions.

Table 6-5 Nationwide Average Percentage Change for Adoption of the LEC Design by Building Type, 10-Year

Building Type	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
APART04	-14.8	-21.2	-21.6	-0.1
APART06	-15.6	-22.9	-23.3	-0.2
DORMI04	-16.9	-22.2	-22.6	-1.2
DORMI06	-15.2	-22.4	-22.8	-0.6
HOTEL15	-13.9	-19.6	-20.0	-0.1
HIGHS02	-10.6	-18.0	-18.5	-1.3
OFFIC03	-23.0	-25.2	-25.3	-2.2
OFFIC08	-21.5	-22.8	-22.8	-2.1
OFFIC16	-15.3	-18.3	-18.5	0.3
RETAIL1	-18.9	-20.9	-21.0	-0.1
RSTRNT1	-30.7	-35.4	-35.6	-4.2
Average	**-17.8**	**-22.6**	**-22.9**	**-1.1**

6.1.3 Results by Climate Zone

Table 6-6 shows the nationwide average change in energy use by *ASHRAE* climate zone for the adoption of the LEC design relative to current state energy codes for all building types. The average reduction in energy use nationwide is 17.8 %. Zone 1 realizes the greatest average reduction in energy use, 22.1 %, while Zone 8 realizes the smallest, 10.2 %. For Zone 1 through Zone 5, the warmer the climate the greater the reduction in energy use, which is a result of the energy efficiency improvement options considered in the LEC design. Warmer climates have an additional option (adding overhangs) that is not beneficial in the colder climates because solar heat gains are beneficial in cold climates and harmful in warm climates.

Zone 7 realizes a greater overall average reduction in energy use (19.8 %) than Zone 6 (16.1 %), Zone 5 (14.9 %), or Zone 4 (18.6 %). To explain this result, the average percentage change in energy use by climate zone is segmented by a location's current energy code in Table 6-6. Considering only the states that have adopted *ASHRAE 90.1-2007*, the average percentage reduction in energy use consistently decreases from Zone 4 (-15.7 %) to Zone 7 (-11.1 %), where the warmer the climate zone, the greater the reduction in energy use.

Table 6-6 Average Percentage Change in Energy Use for LEC by Climate Zone and State Energy Code

Climate Zone/Subzone	Percentage Change by State Energy Code				
	1999	2001	2004	2007	All
1			**-23.1**	**-21.2**	**-22.1**
2	**-38.3**		**-26.4**	**-18.2**	**-20.7**
A	-37.4			-18.3	-19.3
B	-39.2		-26.4	-17.6	-27.4
3	**-32.8**	**-27.4**	**-19.1**	**-18.6**	**-21.3**
A	-32.8	-27.4	-18.5	-17.3	-22.6
B			-21.3	-19.7	-19.8
C				-17.5	-17.5
4	**-27.4**	**-26.4**	**-19.0**	**-15.7**	**-18.6**
A	-26.7	-26.4	-19.0	-15.8	-19.5
B	-31.0			-16.9	-19.7
C				-14.9	-14.9
5	**-27.8**	**-25.1**	**-17.1**	**-13.3**	**-14.9**
A	-25.2	-22.8		-13.1	-13.5
B	-30.4	-25.9	-17.1	-14.3	-17.8
6	**-23.0**	**-22.0**	**-16.1**	**-12.9**	**-16.1**
A	-21.9	-20.8	-16.1	-12.5	-15.1
B	-23.8	-22.7		-13.3	-17.5
7	**-22.7**		**-20.1**	**-11.1**	**-19.8**
8	**-10.2**				**-10.2**
Grand Total	**-25.5**	**-25.2**	**-19.1**	**-15.3**	**-17.8**

Table 6-7 shows that the overall average reduction in energy costs over a 10-year study period ranges from 21.0 % to 25.5 % depending on the climate zone. The greatest overall reductions in energy costs are realized by cities located in Zone 7 followed by Zone 3. Similar to energy use, this result can largely be explained by segmenting the average percentage change in energy costs for a climate zone by a location's current energy code. Considering only the locations that have adopted *ASHRAE 90.1-2007*, the average percentage reductions in energy costs trend lower from the warmer to colder climate zones. However, there is some additional variation that results from each location's average cost per unit of energy. For example, cities in Zone 3 realize the greatest reductions in energy costs, particularly the cities in California located in Subzone 3C, because the state average cost of electricity in California is the 9th highest in the United States, and 2nd highest behind Hawaii of all states that have cities located in the warmer climate zones (Zone 1 through Zone 4).

Table 6-7 Average Percentage Change in Energy Costs for LEC by Climate Zone and State Energy Code, 10-Year

Climate Zone/Subzone	Percentage Change by State Energy Code				
	1999	2001	2004	2007	All
1			**-23.1**	**-21.3**	**-22.2**
2	**-39.5**		**-26.4**	**-20.4**	**-22.6**
A	-39.1			-20.4	-21.4
B	-39.9		-26.4	-20.0	-28.2
3	**-36.8**	**-33.7**	**-22.9**	**-22.2**	**-25.3**
A	-36.8	-33.7	-22.3	-20.2	-26.4
B			-25.0	-23.4	-23.5
C				-25.0	-25.0
4	**-33.5**	**-30.2**	**-21.9**	**-20.2**	**-23.2**
A	-32.9	-30.2	-21.9	-20.3	-24.0
B	-37.2			-23.3	-26.1
C				-18.8	-18.8
5	**-34.9**	**-33.4**	**-21.8**	**-19.4**	**-21.0**
A	-33.3	-26.5		-19.5	-20.0
B	-36.4	-35.7	-21.8	-18.8	-23.3
6	**-30.8**	**-31.6**	**-17.7**	**-16.7**	**-21.2**
A	-29.7	-28.5	-17.7	-16.7	-19.8
B	-31.7	-33.2		-16.7	-23.0
7	**-30.4**		**-19.7**	**-16.8**	**-25.5**
8	**-23.4**				**-23.4**
Grand Total	**-32.4**	**-32.3**	**-21.8**	**-19.7**	**-22.6**

Average energy-related carbon emissions are assumed constant across study period lengths. The data reported in Table 6-8 show that the average reduction in energy-related carbon emissions for the LEC design ranges from 18.5 % to 25.8 % depending on climate zone. Even though carbon emissions are a function of electricity and natural gas consumption, greater reductions in energy use do not necessarily lead to greater reductions in carbon emissions. The greatest reductions in carbon emissions occur in Zone 3 (25.8 %) followed by Zone 7 (25.1 %). The lowest reduction occurs in Zone 8 (18.5 %) followed by Zone 6 (21.3 %) and Zone 5 (21.4 %).

Similar to energy use and energy costs, this result can largely be explained by segmenting the average percentage change in energy-related carbon emissions for a climate zone by a location's current energy code. Considering only the states that have adopted *ASHRAE 90.1-2007*, the average percentage reductions in carbon emissions trend lower from the warmer to colder climate zones. However, there is some additional variation that results from two factors. First, cities that realize a greater shift in energy use from electricity to natural gas realize greater reductions in carbon emissions. Second, cities with a greater differential in average emissions per unit of electricity relative to natural gas will realize greater reductions per unit of energy shifted from natural gas to electricity.

Table 6-8 Average Change in Energy-related Carbon Emissions for LEC by Climate Zone and State Energy Code

Climate Zone/Subzone	Percentage Change by State Energy Code				
	1999	2001	2004	2007	All
1			**-23.9**	**-22.0**	**-23.0**
2	**-40.1**		**-27.3**	**-21.0**	**-23.2**
A	-39.9			-21.0	-22.0
B	-40.3		-27.3	-20.3	-28.8
3	**-38.8**	**-36.2**	**-23.6**	**-22.2**	**-25.8**
A	-38.8	-36.2	-23.3	-21.3	-27.9
B			-24.5	-22.9	-23.0
C				-21.8	-21.8
4	**-36.3**	**-34.8**	**-23.0**	**-20.7**	**-24.3**
A	-35.9	-34.8	-23.0	-21.0	-25.6
B	-38.7			-22.4	-25.7
C				-19.3	-19.3
5	**-37.0**	**-36.1**	**-21.5**	**-19.6**	**-21.4**
A	-36.2	-33.9		-19.8	-20.5
B	-37.9	-36.8	-21.5	-18.9	-23.4
6	**-31.0**	**-32.8**	**-18.4**	**-16.7**	**-21.3**
A	-30.4	-29.6	-18.4	-16.9	-20.1
B	-31.5	-34.5		-16.4	-23.0
7	**-29.3**		**-20.1**	**-17.8**	**-25.1**
8	**-18.5**				**-18.5**
Grand Total	**-32.9**	**-35.1**	**-22.3**	**-20.0**	**-22.9**

The results reported in Table 6-9 show that changes in life-cycle costs vary across climate zones and study periods. The LEC design is cost-effective for all study periods across all climate zones. The percentage reduction in life-cycle costs becomes smaller from the 1-year to 5-year and 10-year study periods, and then slowly increases from the 10-year to 40-year study period. For study period lengths of 10 years or greater, the warmer the climate zone, the greater the percentage reduction in life-cycle costs. For example, the average percentage reduction for the 40-year study period ranges from 3.0 % in Zone 1 to 0.6 % for Zone 8.

Table 6-9 Average Percentage Change in Life-Cycle Costs for LEC by Climate Zone and Study Period

Climate	Study Period Length								
Zone/Subzone	1	5	10	15	20	25	30	35	40
1	**-10.7**	**-3.3**	**-2.5**	**-2.9**	**-2.6**	**-2.7**	**-2.9**	**-3.0**	**-3.0**
2	**-2.7**	**-1.4**	**-1.4**	**-2.1**	**-2.0**	**-2.1**	**-2.3**	**-2.5**	**-2.4**
A	-1.8	-1.1	-1.2	-1.9	-1.7	-1.9	-2.1	-2.2	-2.2
B	-6.9	-2.8	-2.5	-3.4	-3.1	-3.3	-3.5	-3.6	-3.6
3	**-3.1**	**-1.3**	**-1.3**	**-1.6**	**-1.8**	**-2.2**	**-2.4**	**-2.5**	**-2.4**
A	-2.9	-1.3	-1.3	-1.7	-2.0	-2.4	-2.6	-2.7	-2.6
B	-3.4	-1.5	-1.4	-1.6	-1.8	-2.1	-2.3	-2.4	-2.2
C	-2.8	-0.6	-0.6	-0.9	-0.6	-1.0	-1.4	-1.5	-1.4
4	**-2.3**	**-0.9**	**-0.9**	**-1.8**	**-1.6**	**-1.8**	**-2.1**	**-2.2**	**-2.1**
A	-2.2	-0.9	-1.0	-2.0	-1.8	-2.0	-2.3	-2.5	-2.4
B	-2.7	-1.2	-1.2	-2.0	-1.8	-2.1	-2.4	-2.6	-2.4
C	-2.4	-0.4	-0.4	-1.1	-0.8	-0.9	-1.2	-1.3	-1.2
5	**-4.6**	**-1.2**	**-1.0**	**-1.4**	**-1.2**	**-1.3**	**-1.5**	**-1.7**	**-1.7**
A	-3.9	-0.9	-0.9	-1.2	-1.0	-1.2	-1.4	-1.6	-1.6
B	-6.1	-1.7	-1.4	-1.8	-1.5	-1.6	-1.8	-2.0	-1.9
6	**-3.6**	**-0.8**	**-0.8**	**-1.0**	**-0.8**	**-0.9**	**-1.0**	**-1.2**	**-1.1**
A	-3.8	-0.9	-0.9	-1.1	-0.9	-1.1	-1.2	-1.3	-1.2
B	-3.4	-0.7	-0.7	-0.9	-0.7	-0.8	-0.9	-1.0	-0.9
7	**-3.4**	**-0.8**	**-1.0**	**-1.2**	**-1.1**	**-1.2**	**-1.4**	**-1.5**	**-1.5**
8	**-19.4**	**-1.7**	**-0.6**	**-0.5**	**-0.3**	**-0.4**	**-0.6**	**-0.7**	**-0.6**
Average	**-3.8**	**-1.1**	**-1.1**	**-1.5**	**-1.4**	**-1.6**	**-1.8**	**-1.9**	**-1.9**

6.1.4 Results by State Energy Code

One purpose of this study is to determine which states could benefit the most from adopting a more stringent state energy code for commercial buildings. It would be expected that states with energy codes based on older editions of *ASHRAE 90.1*, or no energy code at all, would realize greater benefits from adopting the LEC design because buildings in those states are expected to be built in a less energy efficient manner. Figure 6-2 shows the 14 states with energy codes based on an older edition of *ASHRAE 90.1* (*-2001*) or that have no energy code,[17] many of which are located in the central U.S. as well as a few states in the south, West Virginia, Arizona, Maine, and Alaska.

[17] All maps are generated in ArcMap 10.1.

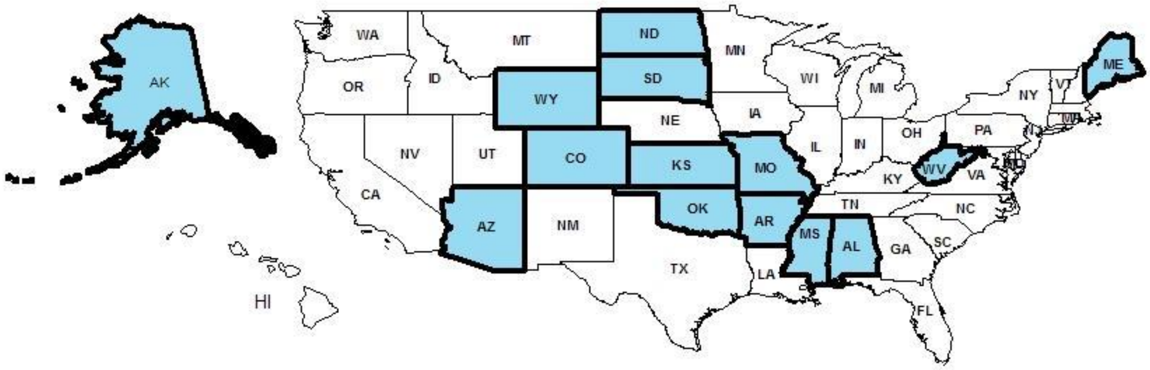

Figure 6-2 States with Energy Standard Editions 2001 or Older or No energy code

It is necessary to assume a particular study period length because energy costs fluctuate on an annual basis. A 10-year study period is used as the baseline because it is one of the most realistic investor time horizons out of the 9 study period length options in BIRDS.

State benefit comparisons are made based on the simple average changes for the cities analyzed in each state by building type. One building type is chosen to illustrate the detailed analysis possible with the powerful BIRDS database compiled for this study. Energy use, energy costs, life-cycle costs, and cradle-to-grave energy-related carbon emissions are analyzed for the most common existing building type, small office buildings. Summary results for the other 10 building types are reported in Table B-1 through Table B-10 in Appendix B. The same interpretations hold for the other ten building types. No states have adopted the LEC design so all should realize impacts across the four metrics listed above.

Table 6-10 summaries the percentage changes in energy use, energy costs, carbon emissions, and life-cycle costs for the 3-story office building. On average, adoption of the LEC design for a 3-story office building decreases energy use, energy costs, and energy-related carbon emissions by more than 20 % each while reducing life-cycle costs. These detailed results can be readily analyzed in mappings of the United States.

Table 6-10 Average Percentage Change by State, 3-Story Office Building, 10-Year

State	Percentage Change: Energy Use	Energy Cost	Carbon	LCC
AK	-25.5	-27.6	-26.9	-0.5
AL	-36.3	-36.6	-36.8	-0.7
AR	-30.4	-33.0	-33.9	-3.8
AZ	-34.7	-34.9	-35.0	-3.1
CA	-24.5	-25.5	-25.1	-3.0
CO	-29.3	-32.1	-32.4	-5.5
CT	-17.9	-23.4	-21.8	-3.1
DE	-20.0	-22.7	-23.2	-3.4
FL	-24.0	-24.3	-24.3	-2.3
GA	-21.6	-22.9	-23.3	-1.2
HI	-28.0	-28.0	-28.0	-5.7
IA	-17.7	-21.4	-21.9	-1.7
ID	-19.7	-22.0	-22.1	-2.7
IL	-17.5	-23.0	-23.0	-2.4
IN	-18.3	-22.4	-23.0	-2.1
KS	-31.9	-34.3	-35.1	0.7
KY	-19.8	-22.4	-23.5	-2.4
LA	-21.9	-22.7	-23.0	-0.3
MA	-17.6	-22.8	-21.8	-2.6
MD	-20.0	-23.4	-23.1	-3.0
ME	-31.1	-31.6	-31.6	-0.7
MI	-16.4	-21.0	-21.5	-2.6
MN	-26.1	-23.7	-23.4	-1.8
MO	-31.6	-33.4	-34.4	1.4
MS	-41.9	-39.1	-39.0	0.4
MT	-18.0	-20.1	-19.9	-1.9
NC	-21.9	-23.3	-23.7	-2.1
ND	-29.5	-30.5	-30.6	0.8
NE	-18.2	-23.0	-23.5	-2.3
NH	-18.1	-20.4	-20.1	-2.8
NJ	-19.6	-23.6	-22.9	-2.5
NM	-23.3	-25.5	-25.6	-3.1
NV	-25.3	-26.7	-26.3	-4.3
NY	-16.9	-22.0	-20.2	-3.0
OH	-17.5	-22.1	-22.7	-2.5
OK	-30.8	-33.7	-35.7	2.0
OR	-21.2	-23.5	-23.6	-3.5
PA	-17.5	-21.5	-22.1	-2.7
RI	-18.5	-22.5	-22.3	-2.8
SC	-23.8	-24.9	-25.0	-2.0
SD	-28.1	-30.2	-30.4	-0.7
TN	-25.3	-25.8	-25.9	-2.6
TX	-21.7	-23.1	-23.1	-1.9
UT	-20.8	-24.6	-23.7	-3.0
VA	-22.1	-24.1	-24.5	-2.2
VT	-17.6	-20.1	-19.8	-2.6
WA	-19.6	-21.9	-22.4	-2.7
WI	-17.5	-20.1	-20.2	-1.7
WV	-30.4	-31.4	-32.4	-4.3
WY	-30.1	-31.8	-31.8	0.3
Avg.	**-23.0**	**-25.2**	**-25.3**	**-2.2**

6.1.4.1 Energy Use, Energy Cost, and Carbon Emissions Savings

Figure 6-3 overlays Figure 6-2 and displays the average percentage energy savings, energy cost savings, and carbon emissions reduction for a 10-year study period by state. The states with codes based on older editions of *ASHRAE 90.1*, or no energy code at all, are shown with cross hatching and bolded state borders. Figure 6-3 shows that 31 of 50 states realize energy use savings of 20 % or more by adopting the LEC design over their current state energy code. Many of the states that realize the greatest energy use savings are the ones that currently have energy codes based on older editions of *ASHRAE 90.1*, or no energy code at all. Of the 18 states that realize energy use savings of at least 25 %, 14 are states with either no energy code or a code based on *ASHRAE 90.1-1999* or *ASHRAE 90.1-2001*, including all 10 states that realize energy use savings of more than 30 %.

The state average percentage reductions in energy costs and carbon emissions are highly correlated with the percentage reductions in energy use. However, the reductions in energy costs and carbon emissions tend to be greater than the reductions in energy use. Figure 6-3 allows for a comparison of the three impacts. A total of 19 states realize an average reduction in energy use of less than 20 %. Meanwhile, all states realize an average reduction in energy costs of greater than 20 % and two states realize an average reduction in carbon emissions of less than 20 %.

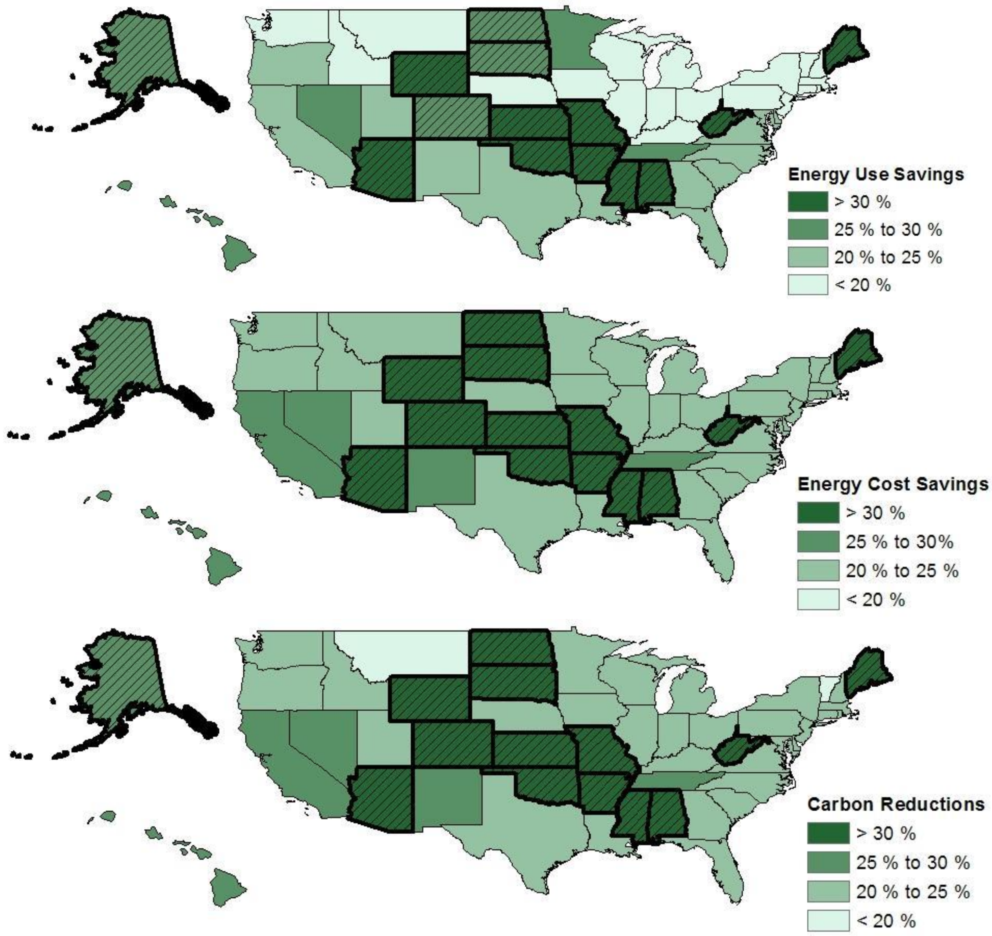

Figure 6-3 Average Energy Use, Energy Cost, and Carbon Emissions Savings by State, 3-Story Office Building, 10-Year

As has been previously discussed, there are two fuel types consumed in each building, natural gas for heating and electricity for all other energy demands (e.g., cooling, plug and process loads, etc.). Electricity and natural gas have different price and emissions rate profiles, with natural gas costing less and being associated with fewer emissions per unit of energy consumed. As a result, the fuel source of reductions in energy use is an important determining factor for the relative savings in energy costs and energy-related carbon emissions per unit of savings in energy use.

Consider the example in Table 6-11, with three alternative building designs that decrease energy use from 100 units to 50 units. Each alternative decreases total energy use by the same amount (50 units or 50 %), but the source of the reduction in energy use varies significantly. Alternative #1 decreases electricity consumption by a greater percentage than natural gas consumption. Alternative #2 decreases electricity and natural gas consumption by the same percentage. Alternative #3 decreases electricity consumption by a smaller percentage than natural gas consumption.

Table 6-11 Fuel Source Reduction Example

Design		Energy Use			% Change		
		Total	Elect.	Gas	%Δ Total	%Δ Elect.	%Δ Gas
	Baseline	100	50	50			
(1)	Electricity Reduction Heavy	50	10	40	-50 %	**-80 %**	-20 %
(2)	Equal Reduction	50	25	25	-50 %	**-50 %**	**-50 %**
(3)	Natural Gas Reduction Heavy	50	40	10	-50 %	-20 %	**-80 %**

The total emissions and energy costs are estimated for the baseline and each building design alternative in Table 6-12 based on the average state energy prices and emissions rates.[18] The percentage changes in carbon emissions and energy costs are greatest for Alternative #1, with reductions of 65 % and 66 %, respectively. Alternative #2 realizes reductions in emissions and energy costs of 50 %. Alternative #3 realizes the smallest percentage reductions in emissions (35 %) and energy costs (34 %).

Table 6-12 Emissions and Energy Costs Associated with Fuel Source Reductions

Design		Emissions			Energy Costs			Relative to Δ Energy Use
		Total	Δ	Δ%	Total	Δ	Δ%	
	Baseline	49 300			650			
(1)	Electricity Reduction Heavy	7 450	-32 210	-65 %	220	-430	-66 %	> 50 %
(2)	Equal Reduction	18 625	-24 650	-50 %	325	-325	-50 %	= 50 %
(3)	Natural Gas Reduction Heavy	29 800	-17 090	-35 %	430	-220	-34 %	< 50 %

Based on these results there are three potential outcomes. First, if the percentage reduction in electricity is *greater* than the percentage reduction in natural gas consumption, then the percentage reduction in energy costs and carbon emissions are *greater* than the percentage reduction in energy use. Second, if the percentage reduction in electricity is *equal* to the percentage reduction in natural gas consumption, then the percentage reduction in energy costs and carbon emissions are *equal* to the percentage reduction in energy use. Third, if the percentage reduction in electricity is *less* than the percentage reduction in natural gas consumption, then the percentage reductions in energy costs and carbon emissions are *less* than the percentage reduction in energy use.

[18] Average state electricity price is 10₵/kWh; average state natural gas price is 3₵/kWh; average state electricity emissions rate is 745 tCO_2e/GWh; average state natural gas emissions rate is 241 tCO_2e/GWh

Now consider an example from the BIRDS database: the average energy use for high schools in Tennessee. Figure 6-4 shows the total energy use for Tennessee's baseline building design, *ASHRAE 90.1-2004*, is greater than the energy use for the two building design alternatives, the *ASHRAE 90.1-2007* and LEC designs. However, the fuel source of the changes in total energy use for *ASHRAE 90.1-2007* and LEC designs are quite different.

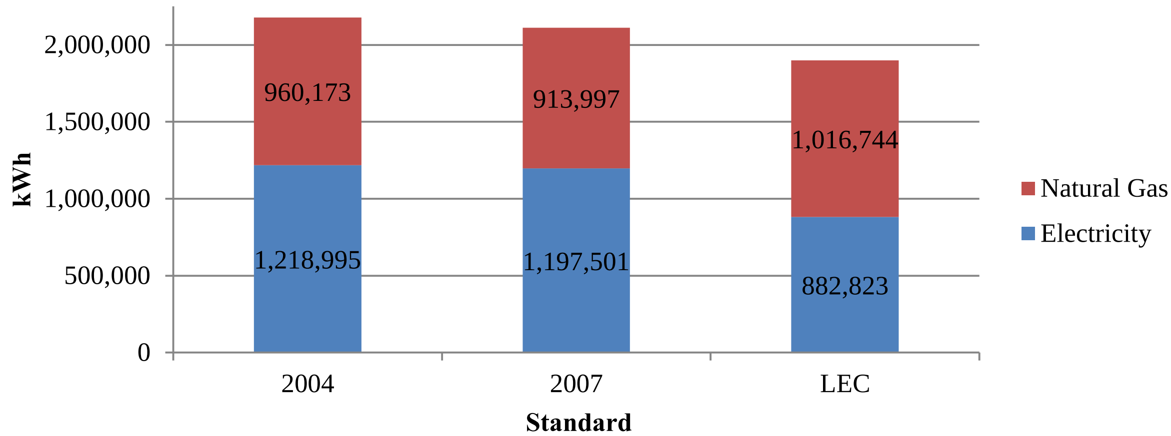

Figure 6-4 Total Energy Use – High School – Tennessee

Figure 6-5 shows the change in energy use for both building designs by fuel source. For the *ASHRAE 90.1-2007* design, natural gas consumption realizes a greater total reduction of 13.5 kWh (46 176 Btu) relative to a reduction in electricity consumption of 6.3 kWh (21 494 Btu). Meanwhile, adopting the LEC design leads to a large reduction in electricity consumption 95.5 kWh (336 172 Btu) while increasing natural gas consumption 16.6 kWh (56 571 Btu). Not only is electricity the primary fuel source for total energy use reductions, there is a shift in fuel consumption from electricity to natural gas.

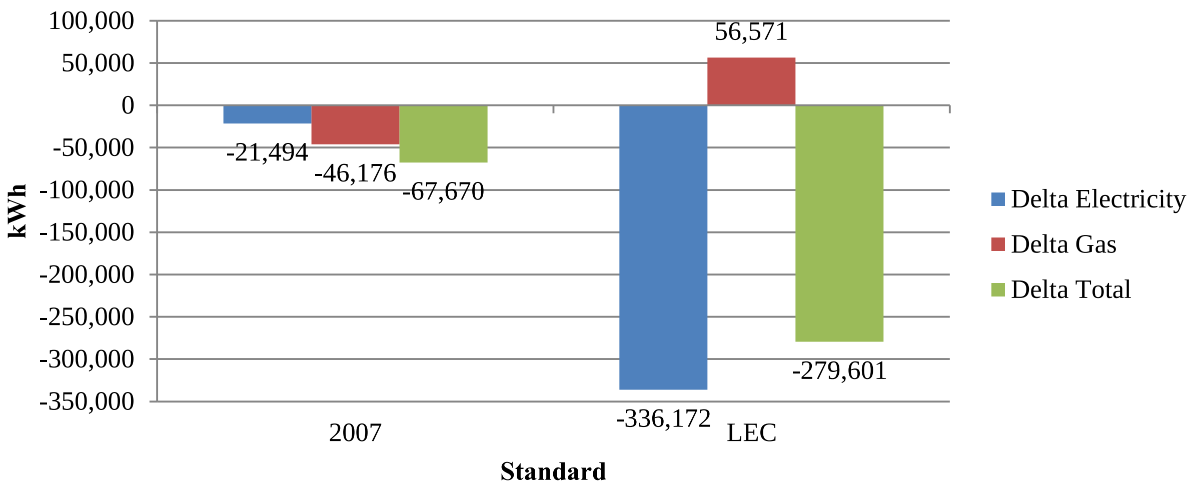

Figure 6-5 Change in Energy Use – High School – Tennessee

Figure 6-6 shows the percentage change in energy use for both building designs and fuel sources. For the *ASHRAE 90.1-2007* design, natural gas consumption realizes a greater percentage reduction (5.1 %) than electricity consumption (1.8 %), which implies that the percentage reduction in energy use will be greater than the percentage reductions in energy costs and carbon emissions. Adopting the LEC design leads to a large percentage decrease in electricity consumption (-38.1 %) and a small percentage increase natural gas consumption (5.6 %). Not only does electricity consumption decrease by a greater percentage than natural gas, electricity accounts for greater than 100 % of the reduction in total energy use, which implies that the percentage reduction in energy costs and carbon emissions will be greater than the reduction in energy use.

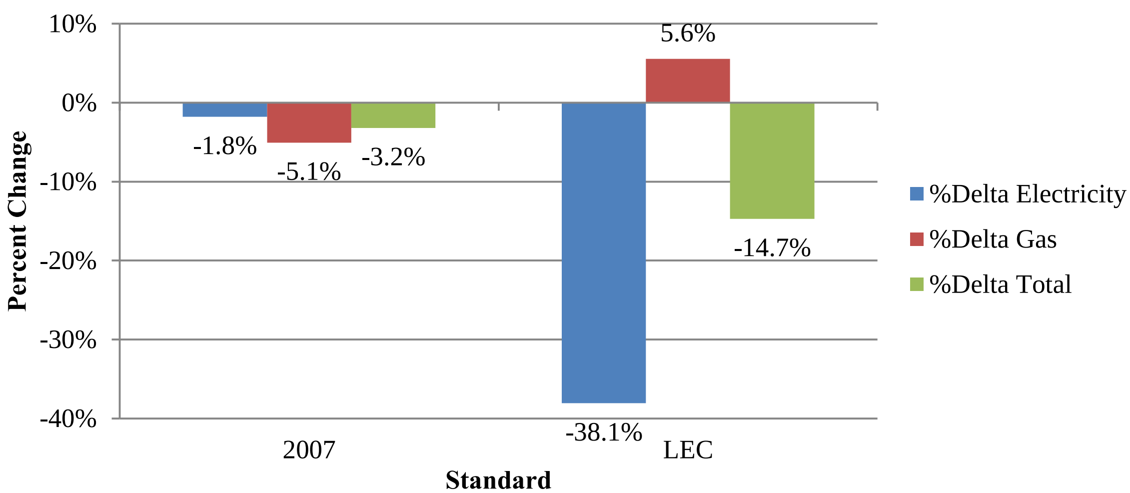

Figure 6-6 Percentage Change in Energy Use – High School – Tennessee

For the LEC design, some of the reduction in electricity consumption is “offset” by an increase in natural gas consumption. A “positive offset” occurs when electricity consumption decreases and natural gas consumption increases. A “negative offset” occurs when both electricity and natural gas consumption decrease. The greater the percentage “offset,” the greater the percentage reduction in energy costs and carbon emissions per percentage reduction in energy use. The offset will be discussed in more detail in Section 6.3.1.

6.1.4.2 Life-Cycle Cost Savings

Figure 6-7 overlays Figure 6-2 with the average life-cycle cost savings for the 3-story office building over 10 years by state from adopting the LEC design. The resulting map shows two interesting trends. First, all states that realize an increase in life-cycle costs on an average percentage basis as a result of adopting the LEC design as its state energy code currently have no state energy code. The energy cost savings of the more efficient LEC design are not enough to overwhelm the additional construction and MRR costs associated with the required energy efficiency measures. Second, states located in the central and southern U.S. tend to realize life-cycle cost savings less than 2 %. States located in the West and Northeast U.S. tend to realize life-cycle cost savings greater than 2 %, which may be a result of greater energy cost savings due to higher energy prices.

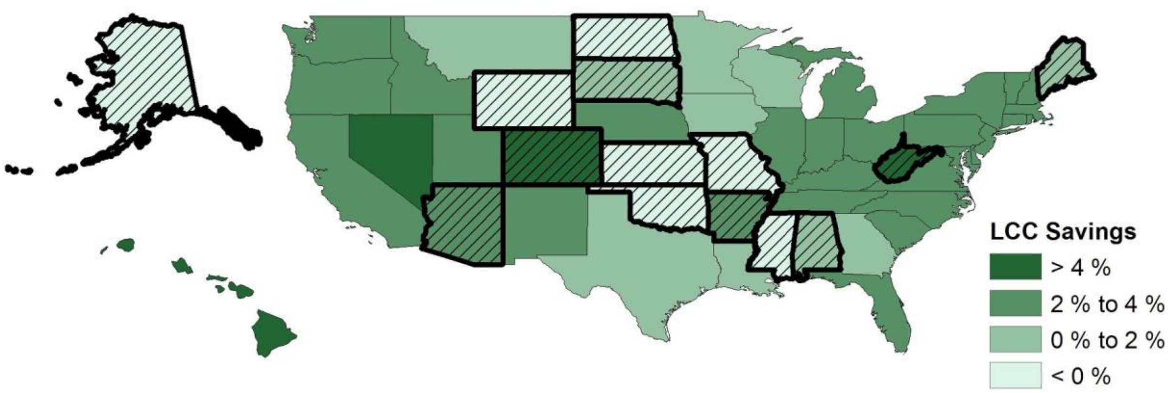

Figure 6-7 Average Life-Cycle Cost Savings by State, 3-Story Office Building, 10-Year

For a 3-story office building and a 10-year study period, states that currently have no energy code or energy codes based on older editions of *ASHRAE 90.1* have the most to gain in percentage terms in energy use, energy cost, and carbon emissions savings in adopting more stringent state energy codes. However, some of these same states realize an average percentage increase in life-cycle costs over the same 10-year study period, raising questions as to the cost-effectiveness of these additional energy efficiency measures.

6.2 Total Changes

The average percentage changes in energy use, energy costs, energy-related carbon emissions, and life-cycle costs reported in Section 6.1 do not account for the amount of new floor area for each building type in a state, which may have a significant impact on the results.

6.2.1 State-Level Total Savings

Estimating the magnitude of the total impacts in a state controls for new floor area and determines which states would benefit the most from adopting the LEC design as their state energy code. The total changes in the four impacts from adopting the LEC design for a state are calculated using Formula 1 defined in Section 5.4. Based on this formula, two variables impact the magnitude of the total changes in a state: the amount of new commercial building construction and the average changes per unit of floor area.

Figure 6-8 shows the amount of new floor area (1000 m^2) constructed annually for each of the 50 states from 2003 to 2007. States with a greater amount of new floor area constructed (California, Florida, and Texas) are expected to realize greater reductions in energy use, energy costs, and carbon emissions.

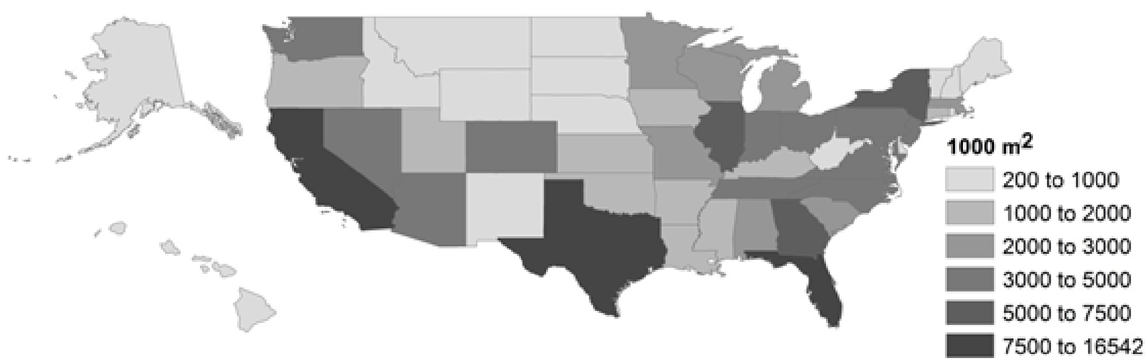

Figure 6-8 Average Annual New Floor Area by State

Table C-1 in Appendix C shows the total savings in energy use, energy costs, carbon emissions, and life-cycle costs from adopting the LEC design as the commercial building energy code for all 50 states for a 10-year study period. In general, the greater the amount of new floor area, the greater the reductions in energy use, energy costs, and carbon emissions. The relative total changes across states, shown in Figure 6-9, are significantly different than the relative percentage changes shown in Figure 6-3, which emphasizes the importance of controlling for the amount of new floor area for each building type in determining the magnitude of the impacts of adopting the LEC design. The total change in energy use for a state is driven by the amount of new floor area constructed in a state. California, Florida, and Texas realize the greatest reductions in energy use (1.9 TWh to

3.8 TWh). In comparison, states with the smallest amount of new floor area (Alaska, Delaware, Montana, Rhode Island, Vermont, and Wyoming) realize savings of less than 0.1 TWh.

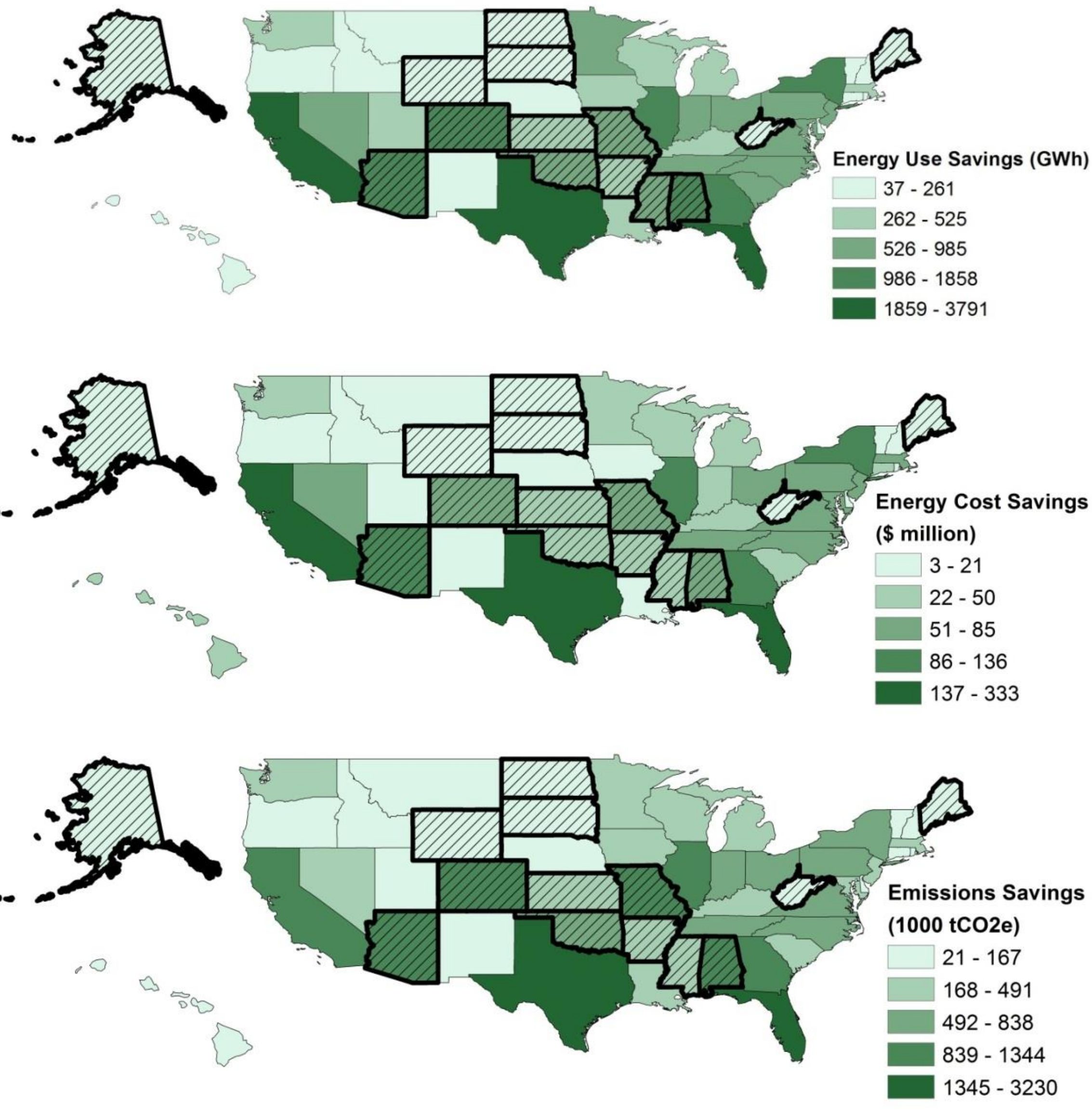

Figure 6-9 Total Energy Use, Energy Costs, and Carbon Emissions Savings by State, 10-Year

Figure 6-9 shows a strong correlation between total savings in energy use and total savings in energy costs and carbon emissions. California, Florida, and Texas realize the greatest reductions in energy costs while Florida and Texas realize the greatest reductions in carbon emissions. The relative total reductions in energy costs and carbon emissions vary from total reductions in energy use to some extent. The reasons for this variation will be discussed in Section 6.3.1.3 and Section 6.3.1.4, respectively.

Figure 6-10 shows a strong correlation between total savings in energy use shown in Figure 6-9 and total savings in life-cycle costs. California, Florida, and Texas realize the greatest total life-cycle cost savings. The relative total reductions in life-cycle costs vary from total reductions in energy use to some extent, particularly for states with no energy code. The reasons for this variation will be discussed in Section 6.3.1.2 and Section 6.4.2.

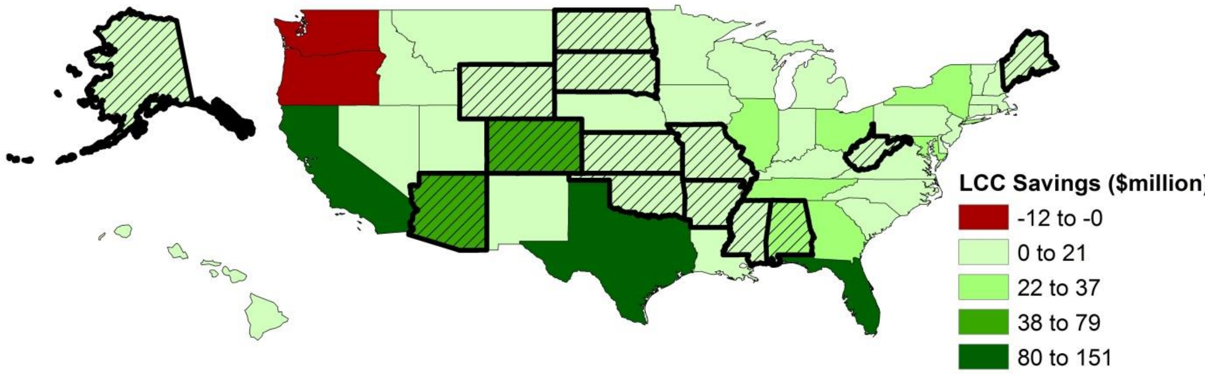

Figure 6-10 Total Life-Cycle Cost Savings by State, 10-Year

Only two states realize an increase in life-cycle costs (Oregon and Washington). Neither of these two states realized an increase in life-cycle costs on a percentage basis. Additionally, seven states that realize an increase in life-cycle costs on a percentage basis for the 3-story office building (see Figure 6-7) realize a total life-cycle cost decrease (Alaska, Kansas, Mississippi, Missouri, North Dakota, Oklahoma, and Wyoming). These results emphasize the importance of accounting for the building types associated with the new floor area constructed in a state to determine where adopting the LEC design is life-cycle cost-effective.

6.2.2 Regional and National Total Savings

The nationwide changes in the four impacts from adopting the LEC design are calculated using Formula 2 from Section 5.4, where the state-level savings are summed across all fifty states for each impact.

Table 6-13 shows the total changes in energy use, energy costs, energy-related carbon emissions, and life-cycle costs for one year's worth of construction for a 10-year study period aggregated at the Census region and national level. The greater the amount of new floor area constructed in a Census region, the greater the total reduction in energy use, energy costs, and life-cycle costs. This condition does not strictly hold for the total reduction in carbon emissions because the total reduction in the Midwest Census Region is greater than the total reduction in the West Census Region. The reason for this variation will be discussed in Section 6.3. The nationwide reductions total 34.4 TWh in energy consumption, $2.8 billion in energy costs, 26.3 million metric tons in energy-related carbon emissions, and $1.0 billion in life-cycle costs for a 10-year study period.

Table 6-13 Total Reductions by Census Region from Adoption of the LEC Design, 10-Year

Census Region	Average Annual New Floor Area 1000 m^2 (1000 ft^2)	Energy Use (GWh)	Energy Costs ($million)	Carbon (1000 tCO_2e)	LCC ($million)
Northeast	22 395 (241 056)	3437	399	2332	125
Midwest	29 510 (317 641)	6621	459	6219	136
South	67 299 (724 394)	16 427	1208	12 890	488
West	36 144 (389 056)	7956	703	4878	300
Total	**155 348 (1 672 147)**	**34 441**	**2769**	**26 319**	**1048**

6.3 Changes per Unit of Floor Area and Energy Use Savings

Total savings in energy use, energy costs, carbon emissions, and life-cycle costs are highly correlated. However, there are a number of factors that lead to significant variation in relative savings, each of which will be discussed in this section.

6.3.1 State Level Changes

There is significant variation in relative savings across states for each of the four impacts for a number of reasons, including current state energy code requirements, newly constructed building stock mix and size, climate zone, electricity costs, electricity production fuel mix (average emissions rate), and the relative percentage changes in fuel types consumed by the building.

6.3.1.1 Energy Use Savings per Unit of Floor Area

Total energy use savings varies across states for a number of reasons. First, states with more newly constructed commercial floor area realize greater reductions in energy use. Second, states located in warmer climate zones realize greater reductions in energy use than the states located in colder climate zones because the buildings in warmer climates benefit more from the overhangs and daylighting installed in the LEC design. Third, a state's current state energy code for commercial buildings drives the variation in energy use.

Table C-2 shows the 10-year reduction in energy use per unit of newly constructed floor area sorted by state in decreasing order. The reduction in energy use per unit of floor area is primarily driven by the state's adopted energy code for commercial buildings. Fourteen of the fifteen states with the greatest per unit reduction from adoption of the LEC design have no state energy code or have *ASHRAE 90.1-2001* as their state energy code.

Additionally, only two of the top 21 states, in terms of per unit savings, have adopted *ASHRAE 90.1-2007*. These results, shown in Figure 6-11, can be compared to the average percentage changes in energy use in Figure 6-3. After controlling for the amount of new floor area, the relative savings across states correlates much closer to the relative average percentage changes in energy use. However, the correlation is not perfect because the total changes weight building types based on new floor area constructed in a state.

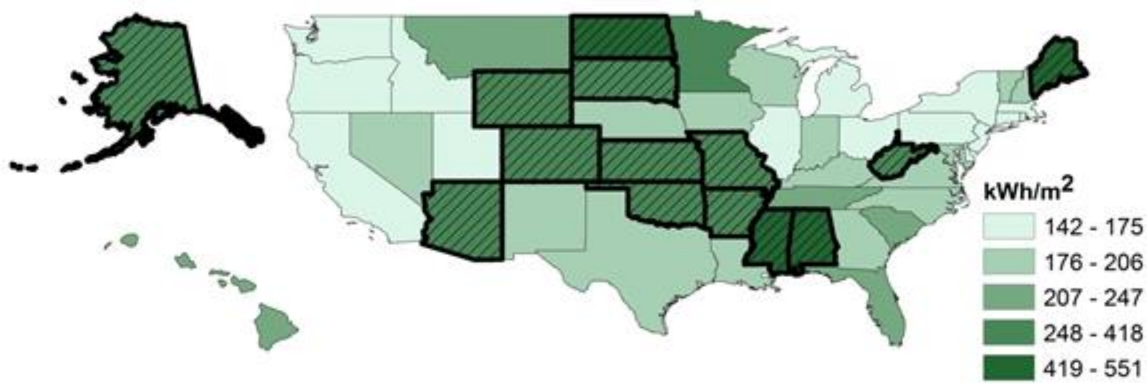

Figure 6-11 Energy Use Savings per Unit of Floor Area by State, 10-Year

6.3.1.2 Life-Cycle Cost Savings per Unit of Floor Area

The relative change in life-cycle costs per unit of new floor area is shown in Table C-3. After controlling for the amount of new floor area, states that have adopted ASHRAE 90.1-2001 as their state energy code (Arkansas, Colorado, and West Virginia) realize some of the greatest relative life-cycle cost savings of adopting the LEC design. There is significant variation in life-cycle cost savings for the ten states with no state energy code, with the relative ranking ranging from 4th (Arizona) to 48th (North Dakota). These results, shown in Figure 6-12, can be compared to the average percentage changes in life-cycle costs in Figure 6-7. Once controlling for the amount of new floor area, the relative savings across states correlates better with the relative percentage changes in energy use. However, the correlation is not perfect because the total changes weight building types based on new floor area constructed.

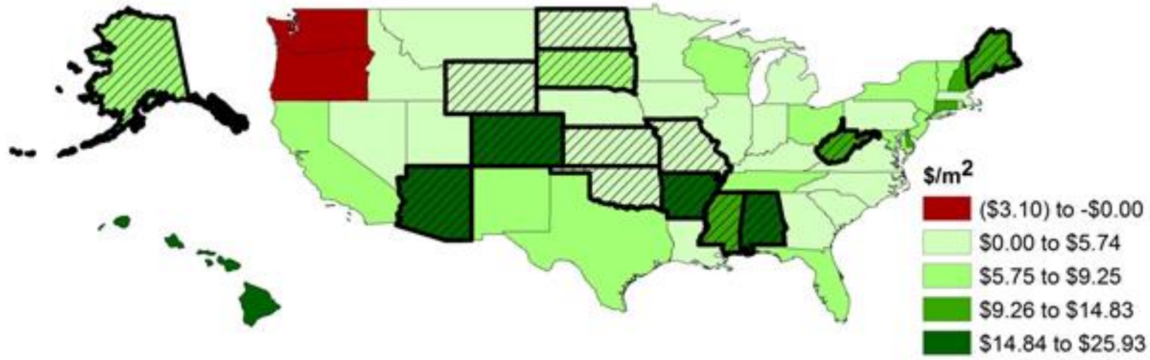

Figure 6-12 Life-Cycle Cost Savings per Unit of Floor Area by State, 10-Yr

6.3.1.3 Energy Cost Savings per Unit of Energy Use Savings

In general, the states that realize the greatest reductions in energy use also realize the greatest reductions in energy costs. However, reductions in energy costs are also impacted by the per unit costs of electricity and natural gas and the fuel mix of the reductions in energy use in a state. Table C-4 shows each state's reduction in energy costs per unit of reduction in energy use, natural gas rate, electricity rate, and the fraction of electricity consumption reductions offset by increases in natural gas consumption.[19] States with the highest electricity rates tend to realize the greatest reductions in energy costs per unit of reduction in energy use. Relative to electricity prices, natural gas prices have minimal impacts on the relative reduction because natural gas prices are fairly constant across states (excluding Hawaii), and are significantly cheaper per unit of energy for all fifty states.

The correlation between a state's average electricity price and the savings in energy costs per unit of energy reduced is shown in Figure 6-13. States in the Northeast, Great Lakes area, California, Hawaii, and Alaska have the highest average electricity prices and realize the greatest savings in energy costs per unit of savings in energy use. Meanwhile, states with the lowest average electricity prices (Northern Central U.S.) realize the smallest energy cost savings per unit of energy use savings.

[19] The fraction of electricity offset by natural gas consumption is greater (less) than 100 % (-100 %) when natural gas consumption increases (decreases) by a greater amount than electricity consumption decreases.

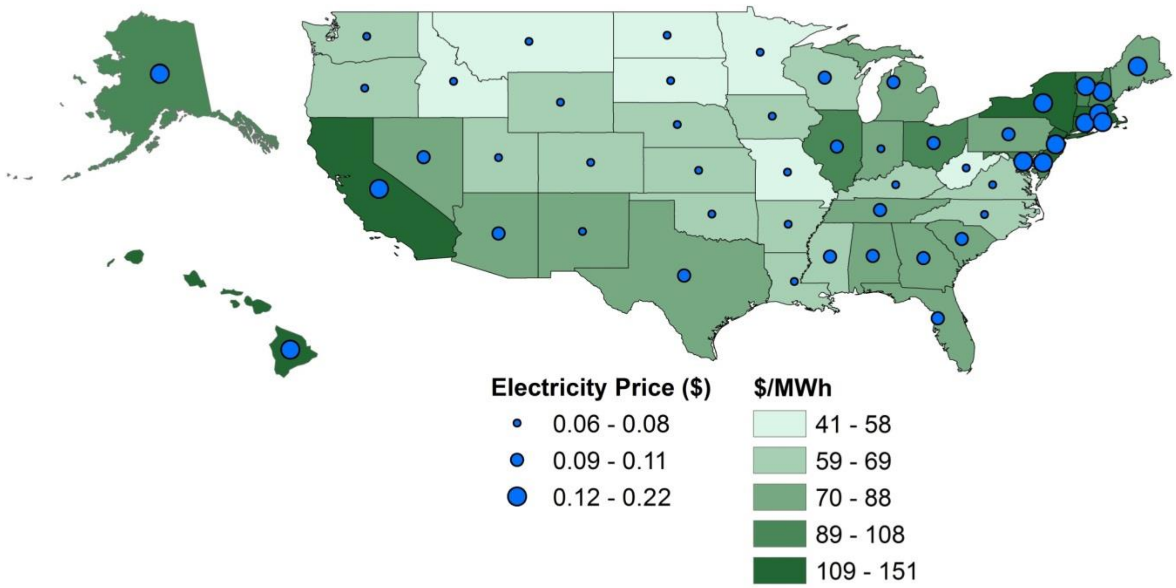

Figure 6-13 Energy Cost Savings per Unit of Energy Use Savings and Average Electricity Price by State

The electricity price does not explain all the variation across states in energy cost savings per unit of energy use savings because there are two sources of energy cost savings: the energy cost savings from total energy use reduction, and the energy cost savings from the shift of fuel consumption from more expensive electricity to cheaper natural gas. The savings from the shift in fuels is a result of two factors: the energy cost savings per unit of energy shifted from electricity to natural gas consumption (energy price differential) and the amount of energy shifted from electricity to natural gas consumption. The energy cost savings increases as the energy price differential increases because the cost savings for each unit of electricity "offset" by a unit of natural gas is greater. The greater the fraction of electricity consumption shifted to natural gas consumption, or offset, the greater the energy cost savings per unit of total energy use savings.

The metric used to explain the shift in fuel consumption is the "weighted average offset," which is the average percentage offset weighted by the amount of new floor area for each building type in a state. Figure 6-14 shows the weighted average offset for each state. Most states realize a positive offset (38 of 50). The northern-most states realize the smallest offset values (-121.2 % to -25.0 %). The greatest offset values are spread across the United States: from the West Coast to the southern central U.S. states to the East North Central and Middle Atlantic Census Divisions.

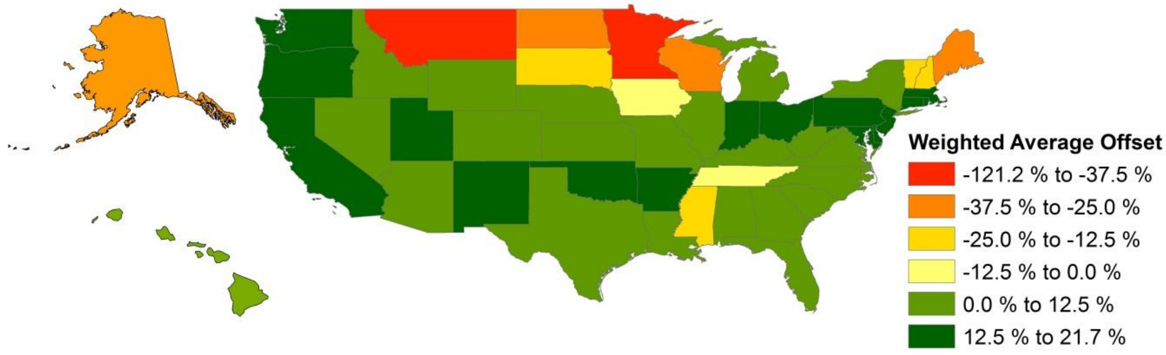

Figure 6-14 Weighted Average Offset by State

Figure 6-15 shows the savings in energy costs per unit of savings in energy use ($/MWh) based on the price differential between electricity and natural gas ($/kWh) and the weighted average offset (%) for each state. States with a greater energy price differential combined with a greater weighted average offset realize the greatest energy cost savings per unit of energy use savings.

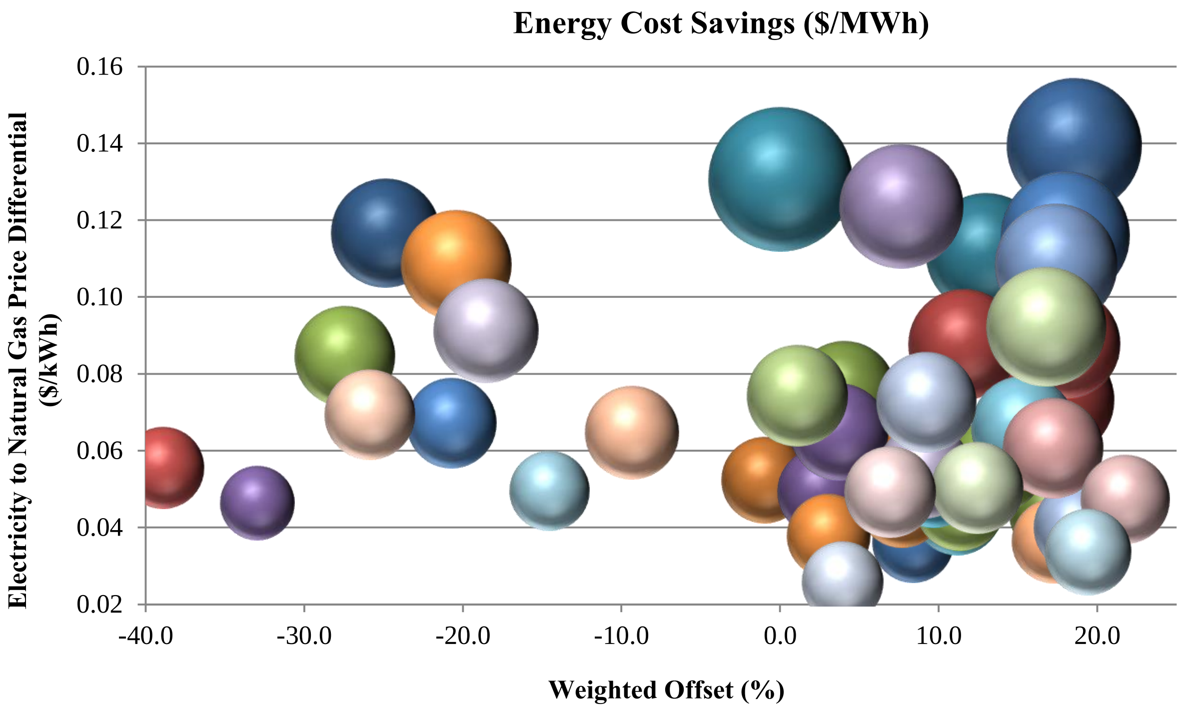

Figure 6-15 Average State Energy Cost Savings per Unit of Energy Use Savings by Weighted Average Offset and Energy Price Differential

6.3.1.4 Carbon Emissions Savings per Unit of Energy Use Savings

In general, the states that realize the greatest reductions in energy use also realize the greatest reductions in energy-related carbon emissions. However, reductions in carbon emissions are also impacted by the per unit emissions rates of electricity and natural gas and the fuel mix of the reductions in energy use in a state. Table C-5 shows the weighted average fraction of electricity consumption offset by a change in natural gas consumption, the average CO_2 emission rates for electricity and natural gas, and the reduction in cradle-to-grave energy-related carbon emissions per unit of reduction in energy use for all 50 states.[20] States with the highest emissions rates for electricity generation tend to realize the greatest reductions in carbon emissions per unit of reduction in energy use. Relative to electricity emissions rates, natural gas has minimal impact on the relative reduction because natural gas emissions rates are constant across states and are significantly lower per unit of energy for all fifty states.

The correlation between a state's average electricity emissions rate and the savings in energy-related emissions per unit of energy reduced is shown in Figure 6-16. States in the central U.S. and the Rust Belt have the highest average electricity emissions rates and realize the greatest savings in carbon emissions per unit of savings in energy use. Meanwhile, states with the lowest average electricity emissions rates (most of the states in the West Census Region and New England Census Division) realize the smallest carbon emissions savings per unit of energy use savings.

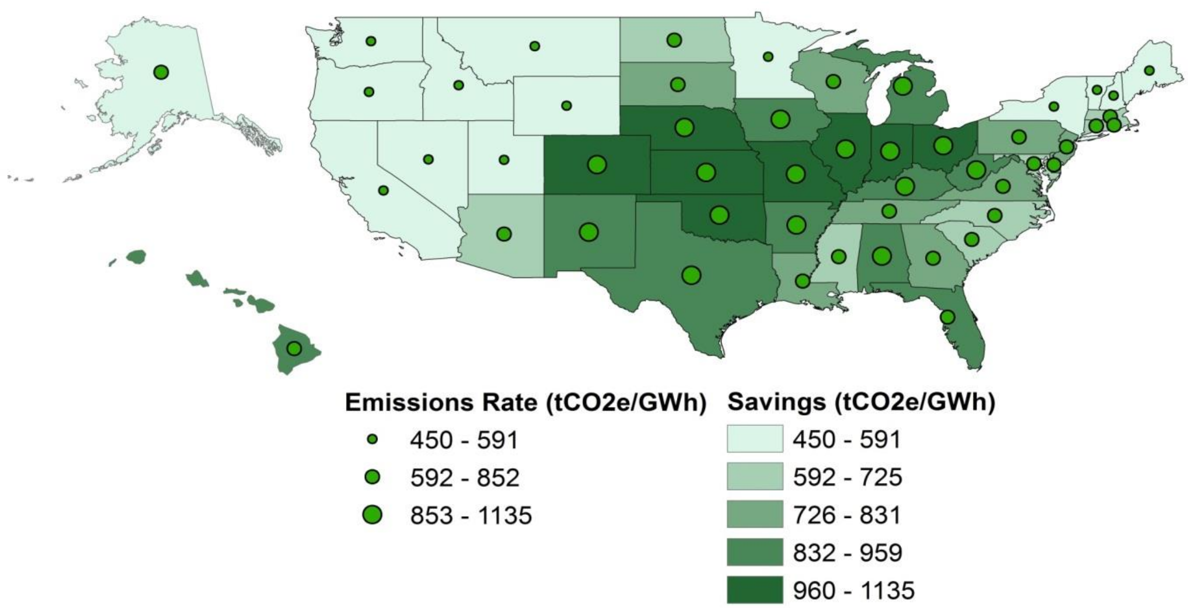

Figure 6-16 Energy-related Carbon Emissions Savings per Unit of Energy Use Savings and Average Electricity Emissions Rate by State

[20] The fraction of electricity offset by natural gas consumption is greater than 100 % when natural gas consumption increases by a greater amount than electricity consumption decreases. The fraction of electricity offset by natural gas consumption is less than -100 % when natural gas consumption decreases by a greater amount than electricity consumption decreases.

The electricity emissions rate does not explain all the variation across states in energy-related carbon emissions savings per unit of energy use savings because there are two sources of carbon emission savings: the carbon emissions savings from total energy use reduction, and the carbon emissions savings from the shifting of fuel consumption from the more carbon intensive electricity to less carbon intensive natural gas. The carbon emissions savings increase as the emissions rate differential increases because the carbon emissions savings for each unit of electricity "offset" by a unit of natural gas is greater. The greater the fraction of electricity consumption reductions offset by increases in natural gas consumption, the greater the carbon emissions savings per unit of energy use savings.

Figure 6-17 shows the savings in carbon emissions per unit of savings in energy use (tCO_2e/GWh) based on the emissions rate differential between electricity and natural gas (tCO_2e/GWh) and the weighted average offset (%) for each state. States with a greater carbon emissions rate differential combined with a greater weighted average offset realize the greatest carbon emissions savings per unit of energy use savings.

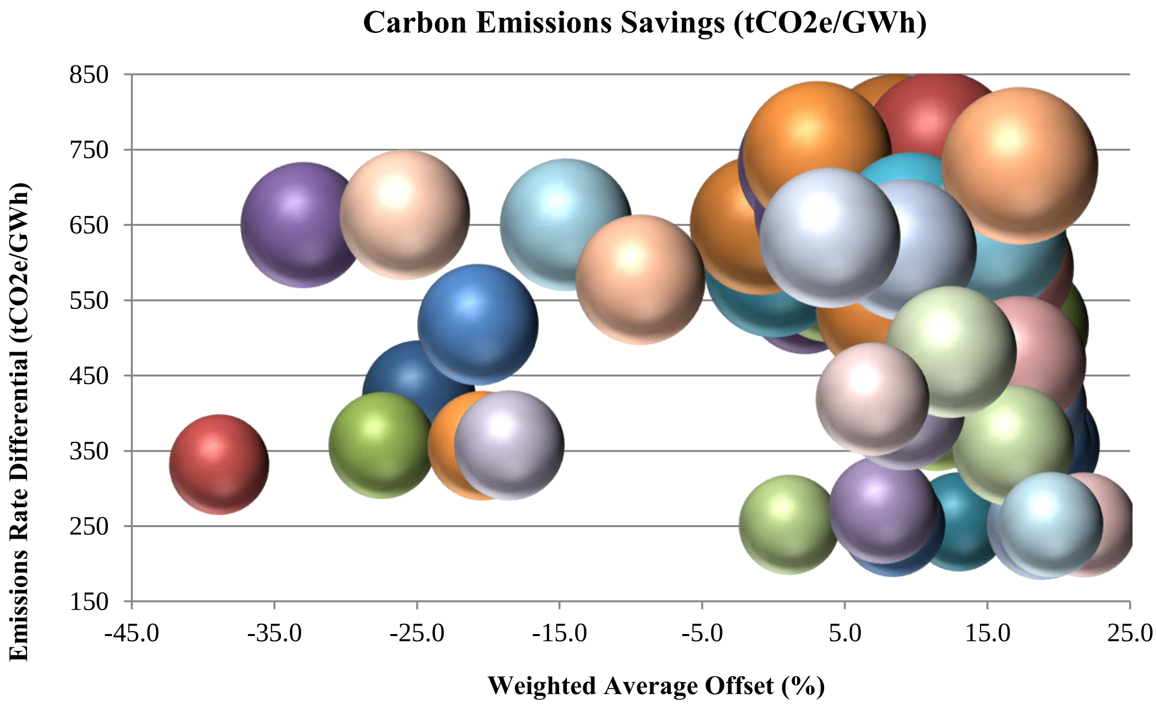

Figure 6-17 Average State Carbon Emissions Savings per Unit of Floor Area by Weighted Average Offset and Energy Emissions Rate Differential

6.3.2 Regional and National Level Changes

Table 6-14 shows the reduction in energy use per unit of newly constructed floor area from adopting the LEC design by Census region. States in the South Census Region realize the greatest reduction while states in the Northeast Census Region realize the smallest reduction in energy use per unit of floor area. The nationwide weighted average reduction in energy use per unit of floor area is 222 kWh/m^2 (21 kWh/ft^2).

Table 6-14 Energy Use Reduction per Unit of Floor Area for Adoption of the LEC Design by Census Region, 10-Year

State	Average Annual New Floor Area 1000 m^2 (1000 ft^2)	Energy Use (GWh)	kWh/m^2	kWh/ft^2
South	67 299 (724 394)	16 427	244	23
Midwest	29 510 (317 641)	6621	224	21
West	36 144 (389 056)	7956	220	20
Northeast	22 395 (241 056)	3437	153	14
Total	**155 348 (1 672 147)**	**34 441**	**222**	**21**

Table 6-15 shows each Census Region's natural gas rate, electricity rate, weighted average fraction of the reduction in electricity consumption offset by the change in natural gas consumption, and average reduction in energy costs from adopting the LEC design. The Northeast Census Region has the highest average electricity rate and weighted average offset, and realizes the greatest reductions in energy costs per unit of reduction in energy use. Meanwhile, the Midwest Census Region has the smallest average electricity rate and weighted average offset, and realizes the smallest reductions in energy costs per unit of reduction in energy use.

Table 6-15 Energy Cost Reduction per kWh of Energy Use Reduction for Adoption of the LEC Design by Census Region, 10-Year

State	Offset* (%)	Electricity Rate* ($/kWh)	Natural Gas Rate* ($/kWh)	Energy Cost Reduction ($/kWh)
Northeast	11.6	0.14	0.03	0.12
West	10.3	0.10	0.03	0.09
South	7.3	0.09	0.03	0.07
Midwest	-4.6	0.09	0.03	0.07
Total	**6.4**	**0.10**	**0.03**	**0.08**
*Weighted by energy use savings for a state				

Table 6-16 shows each Census Region's natural gas emissions rate, electricity emissions rate, weighted average fraction of the reduction in electricity consumption offset by the change in natural gas consumption, and average reduction in carbon emissions from adopting the LEC design. The Midwest Census Region has the highest average electricity emissions rate, and realizes the greatest reductions in carbon emissions per unit of reduction in energy use. Even though the West Census Region does not have the smallest average electricity emissions rate, it realizes the smallest reductions in carbon emissions per unit of reduction in energy use. The Northeast Census Region has a greater offset than the West Census Region, leading to the Northeast realizing greater carbon emissions savings per unit of energy use savings.

Table 6-16 Carbon Reduction per GWh of Energy Use Reduction for Adoption of the LEC Design by Census Region, 10-Year

State	Offset* (%)	CO_2e Emissions Rate for Electricity* (t/GWh)	CO_2e Emissions Rate for Natural Gas (t/GWh)	CO_2e Reduction (t/GWh)
Midwest	-4.6	928	241	939
South	7.3	805	241	785
Northeast	11.6	606	241	678
West	10.3	653	241	613
Total	**3.7**	**805**	**241**	**764**
*Weighted by energy use savings for a state				

Table 6-17 shows the average life-cycle cost reduction per unit of new floor area by Census Region. The combination of greater energy use savings per unit of floor area and higher electricity rates tends to lead to greater life-cycle cost savings from adopting the LEC design. The West Census Region realizes the greatest life-cycle cost savings per unit of floor area because it has the 2^{nd} greatest energy use savings per unit of floor area and the 2^{nd} highest electricity price. Meanwhile the Census regions with the lowest electricity rate (Midwest) and the smallest energy use savings per unit of floor area (Northeast) realize the lowest and 2^{nd}-lowest life-cycle cost savings per unit of floor area, respectively. Other factors that impact life-cycle cost savings include the energy codes and local construction costs.

Table 6-17 Life-Cycle Cost Reductions per Unit of New Floor Area for Adoption of the LEC Design by Census Region, 10-Year

State	Energy Use Savings (kWh/m^2)	Electricity Rate ($/kWh)	LCC Savings ($million)	LCC Savings ($\$/m^2$)	LCC Savings ($\$/ft^2$)
West	220	0.10	300	8.29	0.77
South	244	0.09	488	7.24	0.67
Northeast	153	0.14	125	5.59	0.52
Midwest	224	0.09	136	4.60	0.43
Total	**222**	**0.10**	**1048**	**6.75**	**0.63**

6.4 Within-State Impacts of Adopting Low Energy Case Design

So far, the analysis in this report has focused on across-state, regional, and national variations. However, there is variation in the results across cities within a state. This section will implement a more rigorous statistical approach to analyze the results at the city level: regression analysis using a Least Squares Dummy Variable (LSDV) model.

6.4.1 Energy Use Savings across Cities

As shown in Section 6.1.3, two primary drivers of variation in impacts are the energy code and climate zone of a city. Most cities are required to meet the building requirements of its state energy code, which vary for a given edition of *ASHRAE 90.1* depending on the city's climate zone. However, this does not explain all the variation in the percentage change in energy use across cities. For example, Figure 6-18 shows the average percentage change in energy use for each city in Texas considered in this study. For climate zones in Texas with multiple cities, there is variation in the percentage change in energy use. Consider the cities in Climate Zone 3B, where the variation in energy use savings is 2.8 percentage points (16.6 % to 19.4 %).

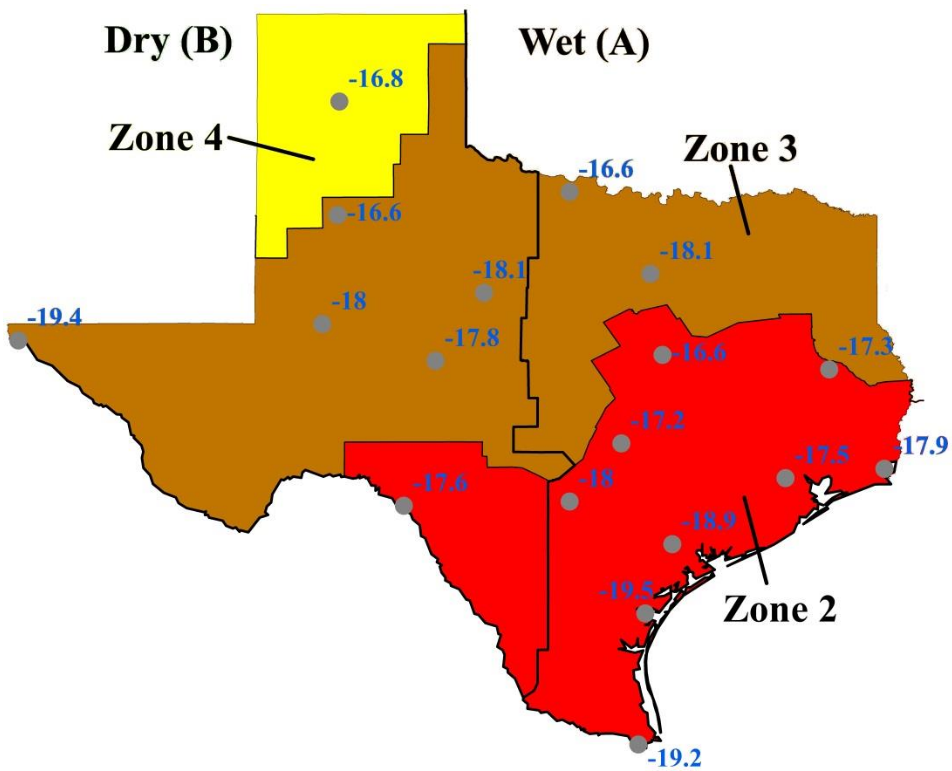

Figure 6-18 Average Percentage Change in Energy Use by City - Texas

Since each climate zone is a bin of heating degree day (HDD) and cooling degree day (CDD) combinations (see *ASHRAE 90.1 Standard*), a city's local climate could vary significantly from other cities' climates even if they are located in the same climate zone. For example, there are five cities in the BIRDS database located in Climate Zone 3B within the state of Texas. Across these five cities, heating varies up to 907 degree days and cooling varies by 606 degree days, which is 35.1 % and 26.6 % of the median city's degree days, respectively. These results are shown in Table 6-18.

Table 6-18 Variation in Energy Use, Heating Degree Days, and Cooling Degree Days for Cities located in Climate Zone 3B in Texas

Cities	Climate Subzone	Low Energy Case		
		Percentage Change in Energy Use	Cooling Degree Days*	Heating Degree Days*
Abilene	3B	-18.1	2410	2558
El Paso	3B	-19.4	2331	2473
Lubbock	3B	-16.6	1804	3380
Midland	3B	-18.0	2278	2673
San Angelo	3B	-17.8	2269	2582
Variation		**2.8**	**606**	**907**
Variation from Median City		**15.6 %**	**26.6 %**	**35.1 %**
***Base 18.3 °C (65 °F)**				

In order to determine the impact of this variation in HDDs and CDDs across cities, it is necessary to use regression analysis. An LSDV model is used to estimate the impact of a city's HDDs and CDDs on the percentage change in energy use realized from adoption of the LEC design while controlling for a city's energy code-climate zone combination. An interaction of the standard edition adopted and climate zone of a city is included in the model because the impact of each standard edition could vary across climate zones due to the different building requirements in each zone.

The LSDV model is defined as:

$$ENERGY\ USE\ CHANGE = \beta_0 + \beta_{k,h}(STD_{k,i} * ZONE_{h,i}) + \beta_1 * HDD65_i + \beta_2 * CDD65_i + \beta_3 * HDD65SQ_i + \beta_4 * CDD65SQ_i$$

Where *ENERGY USE CHANGE* = percentage change in energy use from LEC design adoption
STD_k = binary variables indicating the energy standard edition that a city must meet in building construction
$ZONE_h$ = binary variables indicating the *ASHRAE* climate zone in which a city is located
HDD65 = number of heating degree days at base 18.3 °C (65°F) for a city
CDD65 = number of cooling degree days at base 18.3 °C (65°F) for a city
HDD65SQ = HDD65 squared
CDD65SQ = CDD65 squared

k = {1999, 2001, 2004, 2007}
h = {1,2,3,4,5,6,7,8}
i = index for cities used in analysis

The marginal effect (impact) of variable x_i is the change in ENERGY USE CHANGE as a result of changing variable x_i holding all other variable values constant $\left(\frac{\partial ENERGY\ USE\ CHANGE}{\partial x_i} = \beta_i\right)$.

Seven of the potential 32 energy code-climate zone combinations nationwide are excluded from the model because not all energy standard editions are adopted for each climate zone. For example, *ASHRAE 90.1-2001* is only adopted in three states, which span four climate zones. Of the 25 energy code-climate zone interaction variables shown in Table 6-19, only 24 have coefficient values because the 25^{th} coefficient value is contained in the constant coefficient as a result of variable multicollinearity (the dummy variable trap), and is the baseline against which the other 24 coefficients are compared. In this model *STD2004*ZONE1* is the baseline.

The 25 energy code-climate zone interaction variable coefficients estimate the impact a city's baseline energy code has on ENERGY USE CHANGE by adopting the LEC design. The coefficients on the STD1999 and STD2001 interaction variables are all negative and statistically significant. Relative to cities that build to meet *ASHRAE 90.1-2004* located in Zone 1, cities that build to meet *ASHRAE 90.1-1999* and *-2001* decrease the percentage change in energy use by 11.5 to 17.4 percentage points and 10.4 to 11.6 percentage points, respectively, depending on the climate zone. Only two of the STD2004 interaction variable coefficients are statistically significant and decrease the percentage change in energy use (6.2 percentage points in Zone 2 and 12.9 percentage points in Zone 7). None of the STD2007 interaction variables are statistically significant. Based on these results, the older the edition of *ASHRAE 90.1* to which a city must build, the greater the percentage decrease in energy use. Additionally, the climate zone in which a city is located impacts the magnitude of the decrease. Both of these results reiterate the previous interpretations in this report.

Table 6-19 Regression Analysis – Percentage Change in Energy Use from Adopting the LEC Design by City

ENERGY USE CHANGE	
Variables	**Coefficient**
HDD65	**0.00177*** **
HDD65SQ	-1.52e-09
CDD65	**0.00185** **
CDD65SQ	-3.45e-07
STD1999 * ZONE2	**-17.36*** **
STD1999 * ZONE3	**-15.26*** **
STD1999 * ZONE4	**-12.89*** **
STD1999 * ZONE5	**-13.72*** **
STD1999 * ZONE6	**-11.47*** **
STD1999 * ZONE7	**-14.08*** **
STD1999 * ZONE8	**-12.65** **
STD2001 * ZONE3	**-10.40*** **
STD2001 * ZONE4	**-11.57*** **
STD2001 * ZONE5	**-11.54*** **
STD2001 * ZONE6	**-10.85*** **
STD2004 * ZONE1	
STD2004 * ZONE2	**-6.246** **
STD2004 * ZONE3	-1.046
STD2004 * ZONE4	-3.626
STD2004 * ZONE5	-4.882
STD2004 * ZONE6	-6.198
STD2004 * ZONE7	**-12.90*** **
STD2007 * ZONE1	2.111
STD2007 * ZONE2	1.903
STD2007 * ZONE3	-0.113
STD2007 * ZONE4	1.010
STD2007 * ZONE5	-0.501
STD2007 * ZONE6	-2.692
STD2007 * ZONE7	-1.796
CONSTANT	**-24.83*** **
Observations	228
Adj. R-squared	0.785
Bolded coefficients are statistically significant at the following: *** $p<0.01$, ** $p<0.05$, * $p<0.1$	

Four variables are included in the model to control for local climate. Two of the variables are the total HDDs at base 18.3 °C (65°F) (HDD65) and total CDDs at base 18.3 °C (65°F) (CDD65) for a city. Additionally, two higher ordered terms (HDD65SQ and

CDD65SQ) are included in the model to control for potential non-linear impacts of heating and cooling degree days. The coefficients for HDD65 and CDD65 are positive and statistically significant, with a two standard deviation increase in HDD65 (5358) and CDD65 (2066) leading to a 9.3 percentage point increase and 3.8 percentage point increase in the percentage change in energy use, respectively. The coefficient for HDD65SQ is statistically insignificant, and the coefficient for CDD65SQ is negative and nearly significant at the 10 % level.[21]

Consider the example of the five cities in Climate Zone 3B in Texas. Based on the coefficients for the four HDD and CDD variables and the HDD and CDD values for Lubbock and El Paso, the model predicts that El Paso's energy use change should be 1.4 percentage points lower than in Lubbock, which is half the observed variation.[22] The squared partial correlation for the HDD and CDD variables (HDD65, CDD65, HDD65SQ, and CDD65SQ), which is the proportion of variance in the dependent variable (ENERGY USE CHANGE) not associated with any other explanatory variables in the model that is explained by the HDD and CDD variables, is 10.6 %. The model appears to explain a significant portion (two-thirds) of the observed variation in ENERGY USE CHANGE for the cities in Climate Zone 3B in Texas (15.6 %).

6.4.2 Life-Cycle Cost Savings across Cities

Similar to energy use, the energy code and climate zone are important factors in determining the percentage change in life-cycle costs for a city. Additionally, the state-level energy prices for a city will drive variation across states. However, there is some variation across cities within the same energy code-climate zone combination because local construction costs vary across cities as measured by the city construction cost index discussed in Section 3.1. Consider the same five cities in Climate Zone 3B in Texas discussed in the previous Section 6.4.1. Table 6-20 shows that the percentage change in life-cycle costs and the city construction cost index varies across cities, although to a lesser extent than do heating degree days and cooling degree days for energy use.

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[21] Non-linearity in the degree day variables was suspected because when cities building to meet *ASHRAE 90.1-2007* were excluded from the regression, CDD65 became statistically significant in the model.

[22] The model predicts a nationwide average impact for a variable, which means that the predicted impact will not necessarily match the observed impact for the comparison of two specific data points.

Table 6-20 Regression Analysis, Within State Variation in Life-Cycle Costs

Cities	Climate Subzone	Low Energy Case	
		Percentage Change in Life-cycle Costs	City Construction Cost Index
Abilene	3B	-1.3	0.783
El Paso	3B	-1.4	0.775
Lubbock	3B	-1.3	0.795
Midland	3B	-1.4	0.779
San Angelo	3B	-1.4	0.757
Max – Min		**0.1**	**0.038**
Variation from Median City		**7 %**	**5 %**

Similar to the model estimating energy use, an LSDV model is used to estimate the impact of a city's local construction cost index value on the percentage change in life-cycle costs while controlling for a city's energy code-climate zone combination and state-level energy prices. An interaction of the standard edition adopted and climate zone of a city is included in the model because the impact of each standard edition could vary across climate zones due to the different building requirements in each zone.

The LSDV model is defined as:

$$LCC\ CHANGE = \beta_0 + \beta_{k,h}(STD_{k,i} * ZONE_{h,i}) + \beta_1 * ELECT\ PRICE_i + \beta_2 * GAS\ PRICE_i + \beta_3 * CITY\ COST\ INDEX_i$$

Where *LCC CHANGE* = percentage change in life-cycle costs from LEC design adoption
STD_k = binary variables indicating the energy standard edition that a city must meet in building construction
$ZONE_h$ = binary variables indicating the *ASHRAE* climate zone in which a city is located
ELECT PRICE = state average electricity price
GAS PRICE = state average natural gas price
CITY COST INDEX = local city construction cost index
k = {1999, 2001, 2004, 2007}
h = {1,2,3,4,5,6,7,8}
i = index for cities used in analysis

The marginal effect (impact) of variable x_i is the change in LCC CHANGE as a result of changing variable x_i holding all other variable values constant $\left(\frac{\partial LCC\ CHANGE}{\partial x_i} = \beta_i\right)$.

Seven of the potential 32 energy code-climate zone combinations nationwide are excluded from the model because not all energy standard editions are adopted for each climate zone. For example, *ASHRAE 90.1-2001* is only adopted in three states, which span four climate zones. Of the 25 energy code-climate zone interaction variables shown in Table 6-21, only 24 have coefficient values because the 25th coefficient value is contained in the constant coefficient as a result of variable multicollinearity (the dummy variable trap), and is the baseline against which the other 24 coefficients are compared. In this model *STD2007*ZONE7* is the baseline.

The 25 energy code-climate zone interaction variable coefficients estimate the impact a city's baseline energy code has on LCC CHANGE. The coefficients on the STD2001 interaction variables are negative and statistically significant. Four, three, and one coefficient for the STD2004, STD1999, and STD2007 interaction variables are negative and statistically significant. Cities building to meet *ASHRAE 90.1-2001* realize greater additional percentage point reductions (2.0 to 2.8) in life-cycle costs relative to cities building to meet *ASHRAE 90.1-1999* (0.0 to 1.7), *ASHRAE 90.1-2004* (0.0 to 2.2), and *ASHRAE 90.1-2007* (0.0 to 1.0). The magnitude of the impacts varies depending on the climate zone of the city.

The coefficient on a state's electricity price (ELECT PRICE) is statistically significant while the coefficient on natural gas price (GAS PRICE) is statistically insignificant. A greater electricity price leads to lower life-cycle costs, with a two standard deviation in electricity price (5.3¢/kWh) decreasing life-cycle costs by 0.9 percentage points. The squared partial correlation for ELECT PRICE, which is the proportion of variance in the dependent variable (LCC CHANGE) not associated with any other explanatory variables in the model that is explained by ELECT PRICE, is greater than any other variable in the model at 47.3 %. There is a strong correlation between a city's average electricity price and its percentage change in life-cycle costs realized from adoption of the LEC design.

Table 6-21 Regression Analysis – Percentage Change in Life-cycle Costs from Adopting the LEC Design by City

LCC CHANGE	
Variables	**Coefficient**
Elect Price	**-16.62*** **
Gas Price	6.490
City Cost Index	**1.824*** **
STD1999 * ZONE2	**-1.698*** **
STD1999 * ZONE3	**-0.714*** **
STD1999 * ZONE4	0.102
STD1999 * ZONE5	**-0.598***
STD1999 * ZONE6	-0.0128
STD1999 * ZONE7	-0.0910
STD1999 * ZONE8	0.436
STD2001 * ZONE3	**-2.752*** **
STD2001 * ZONE4	**-2.048*** **
STD2001 * ZONE5	**-2.349*** **
STD2001 * ZONE6	**-2.198*** **
STD2004 * ZONE1	**-2.172*** **
STD2004 * ZONE2	**-1.971*** **
STD2004 * ZONE3	-0.261
STD2004 * ZONE4	**-0.604** **
STD2004 * ZONE5	**-0.816** **
STD2004 * ZONE6	-0.458
STD2004 * ZONE7	-0.503
STD2007 * ZONE1	**-1.009*** **
STD2007 * ZONE2	-0.168
STD2007 * ZONE3	-0.134
STD2007 * ZONE4	-0.238
STD2007 * ZONE5	-0.0394
STD2007 * ZONE6	0.0868
STD2007 * ZONE7	
Constant	**-1.052*** **
Observations	228
Adj. R-squared	0.813
Bolded coefficients are statistically significant at the following: *** p<0.01, ** p<0.05, * p<0.1	

The coefficient for the local city construction cost index (CITY COST INDEX) is statistically significant, with a two standard deviation in the index (0.21) leading to a 0.4 percentage point increase in life-cycle costs. The more expensive it is to construct a building, the smaller the decrease in life-cycle costs. Once again consider the example of the five cities in Climate Zone 3B in Texas. Based on the regression results, the variation in the city construction cost index (0.038) leads to a predicted variation of 0.07

percentage points in the change in life-cycle costs, or 70 % of the observed variation.[23] The squared partial correlation for CITY COST INDEX, which is the proportion of variance in the dependent variable (LCC CHANGE) not associated with any other explanatory variables in the model that is explained by the CITY COST INDEX, is 14.8 % compared to the 7 % observed variation in LCC CHANGE for the cities in Climate Zone 3B in Texas. The city construction cost index accounts for more than enough variation in the model to explain the observed variation in the percentage change in life-cycle costs for cities located Zone 3B in Texas.

[23] The percentage change data have been rounded to one decimal, which leads to some uncertainty as to the impact explained by the city cost index. Also, the model predicts a nationwide average impact for a variable, which means that the predicted impact will not necessarily match the observed impact for the comparison of two specific data points.

7 Nationwide Impacts of Adopting *ASHRAE 90.1-2007*

This section analyzes benefits from nationwide adoption of the *ASHRAE 90.1-2007* design relative to the current collection of state energy codes. Benefits are evaluated across several dimensions: time, building type, geography (climate zone and state), and energy code. There are three metrics used to analyze the results: percentage changes, total changes, and changes per unit of floor area. The analysis only includes states that have not yet adopted *ASHRAE 90.1-2007*.

7.1 Percentage Changes

The initial metrics used to estimate the impacts of adopting the *ASHRAE 90.1-2007* design are the average percentage changes in energy use, energy costs, carbon emissions, and life-cycle costs. Impacts are evaluated across four dimensions: study period length, building type, climate zone, and state energy code.

7.1.1 Results by Study Period Length

It is important to consider how the study period length – representing the time horizon of the investor -- impacts energy use, energy costs, energy-related carbon emissions, and life-cycle costs. Nine study periods are analyzed: 1 year, 5 years, 10 years, 15 years, 20 years, 25 years, 30 years, 35 years, and 40 years.

The average reduction in energy use from adoption of *ASHRAE 90.1-2007* is constant over all study period lengths because energy efficiency is assumed to be constant over time. Table 7-1 shows that the national average change in energy use across the 73 cities in the analysis ranges from -15.6 % to 0.5 %, depending on the building type, with an overall national average of -9.6 %. The 16-story office building realizes a percentage increase in energy use because the relaxation of the window requirements overwhelms the impacts from the other energy efficiency measures required by *ASHRAE 90.1-2007*.

Table 7-1 Nationwide Average Percentage Change in Energy Use from Adoption of *ASHRAE 90.1-2007* by Building Type

Building Type	Percentage Change
APART04	-11.4
APART06	-11.0
DORMI04	-12.3
DORMI06	-10.7
HOTEL15	-3.2
HIGHS02	-5.8
OFFIC03	-11.4
OFFIC08	-9.8
OFFIC16	0.5
RETAIL1	-15.2
RSTRNT1	-15.6
Average	**-9.6**

As shown in Table 7-2, savings in energy costs vary slightly, in percentage terms, over increasing study period lengths. The national average change in energy costs across all location-building type combinations ranges from -12.3 % to -12.0 % for all study period lengths. There is minor variation of up to 0.6 percentage points for some building types across study periods as a result of the escalation rates used to adjust future energy prices, which vary by U.S. Census Region.

Table 7-2 Nationwide Average Percentage Change in Energy Costs from Adoption of *ASHRAE 90.1-2007* by Building Type and Study Period Length

Building Type	Study Period Length								
	1	5	10	15	20	25	30	35	40
APART04	-16.9	-16.7	-16.7	-16.6	-16.5	-16.4	-16.3	-16.3	-16.3
APART06	-16.6	-16.4	-16.3	-16.2	-16.2	-16.1	-16.0	-16.0	-16.0
DORMI04	-17.4	-17.3	-17.2	-17.1	-17.1	-17.0	-16.9	-16.9	-16.9
DORMI06	-16.5	-16.4	-16.3	-16.2	-16.1	-16.0	-16.0	-16.0	-16.0
HOTEL15	-8.3	-8.2	-8.1	-8.0	-8.0	-7.9	-7.8	-7.8	-7.8
HIGHS02	-7.8	-7.7	-7.7	-7.7	-7.6	-7.6	-7.6	-7.6	-7.6
OFFIC03	-10.6	-10.6	-10.6	-10.6	-10.6	-10.7	-10.7	-10.7	-10.7
OFFIC08	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5
OFFIC16	-0.9	-0.8	-0.8	-0.8	-0.8	-0.8	-0.7	-0.7	-0.7
RETAIL1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1
RSTRNT1	-15.5	-15.5	-15.5	-15.5	-15.5	-15.5	-15.5	-15.5	-15.5
Average	**-12.3**	**-12.2**	**-12.2**	**-12.1**	**-12.1**	**-12.1**	**-12.0**	**-12.0**	**-12.0**

Since the national average reduction in energy use across all location-building type combinations is constant over all study period lengths, the average change in energy-related carbon emissions is also constant at -15.6 %. The national average change in carbon emissions ranges from -17.9 % to -0.9 % depending on the building type, as shown in Table 7-3.

Table 7-3 Nationwide Average Percentage Change in Carbon Emissions from Adoption of *ASHRAE 90.1-2007* by Building Type

Building Type	Percentage Change
APART04	-17.4
APART06	-17.1
DORMI04	-17.9
DORMI06	-17.1
HOTEL15	-8.8
HIGHS02	-8.2
OFFIC03	-10.5
OFFIC08	-9.3
OFFIC16	-0.9
RETAIL1	-15.0
RSTRNT1	-15.6
Average	**-12.4**

Table 7-4 shows that the percentage change in life-cycle costs varies slightly over increasing study period lengths, with the average change across all location-building type combinations ranging from -1.9 % for a 1-year study period to -0.7 % for a 10-year study period. The national average change in life-cycle costs ranges from -6.7 % to 2.3 % depending on the building type for a 1-year study period. The nationwide change in life-cycle costs averages -0.7 % for a 10-year study period length, ranging from -1.7 % to 0.5 % depending on the building type. As the study period length increases from 10 years to 40 years, the percentage reduction in national average life-cycle costs increases, with an overall average percentage change of -0.7 % to -1.1 %, respectively. Also, the number of building types that realize reductions in life-cycle costs increases from 7 for a 20-year study period to 10 for a 40-year study period.

Table 7-4 National Average Percentage Change in Life-Cycle Costs from Adoption of *ASHRAE 90.1-2007* by Building Type and Study Period Length

Building Type	Study Period Length								
	1	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
APART04	-1.8	-1.8	-1.7	-1.8	-1.9	-1.9	-1.9	-2.0	-2.0
APART06	-1.1	-1.6	-1.6	-1.8	-1.8	-1.9	-1.9	-2.0	-2.0
DORMI04	-4.1	-1.1	-0.9	-1.0	-1.1	-1.2	-1.2	-1.3	-1.4
DORMI06	-2.1	-2.1	-2.0	-2.1	-2.1	-2.2	-2.2	-2.3	-2.3
HOTEL15	-1.4	-1.3	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2
HIGHS02	-1.4	-0.8	-0.8	-0.9	-0.9	-1.0	-1.1	-1.1	-1.1
OFFIC03	-3.1	0.4	0.5	0.3	0.2	0.1	0.1	0.0	-0.1
OFFIC08	0.2	0.6	0.5	0.3	0.1	-0.0	-0.0	-0.1	-0.2
OFFIC16	-1.5	-0.3	-0.1	0.1	0.1	0.2	0.2	0.2	0.3
RETAIL1	-6.7	-1.2	-0.9	-1.1	-1.2	-1.3	-1.4	-1.4	-1.5
RSTRNT1	2.3	0.8	0.4	0.0	-0.2	-0.4	-0.5	-0.6	-0.7
Average	**-1.9**	**-0.8**	**-0.7**	**-0.8**	**-0.9**	**-1.0**	**-1.0**	**-1.1**	**-1.1**

7.1.2 Results by Building Type

Table 7-5 shows the simple average changes, in percentage terms, from adopting *ASHRAE 90.1-2007* by building type for a 10-year study period length. The tallest buildings realize the lowest reductions in energy use. The only building type that realizes an increase in energy use is the 16-story office building. The hotel and high school realize reductions in energy use of 3.2 % and 5.8 %, respectively. The remaining building types all realize reductions in energy use greater than 9.8 %. All building types realize reductions in energy costs, ranging from 0.8 % to 17.2 %. The 16-story office building realizes small reductions in energy costs even though its energy use increases because energy use is shifted from electricity to natural gas. The apartments and dormitories realize the greatest reductions in energy costs. All building types realize reductions in energy-related carbon emissions, ranging from 0.9 % to 17.9 %. The greatest reductions in carbon emissions are realized by the apartment buildings and dormitories at over 15.0 % while the smallest reductions are realized by the 16-story office building. Of the 11 building types, 8 realize a decrease in life-cycle costs. The greatest reductions in life-cycle costs are realized by the 6-story dormitory (2.0 %) and 4-story apartment building (1.7 %). The greatest life-cycle cost increases are realized by the 3-and 8-story office buildings (0.5 % each) and the restaurant (0.4 %).

Table 7-5 Nationwide Percentage Change for *ASHRAE 90.1-2007* by Building Type, 10-Year

Building Type	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
APART04	-11.4	-16.7	-17.4	-1.7
APART06	-11.0	-16.3	-17.1	-1.6
DORMI04	-12.3	-17.2	-17.9	-0.9
DORMI06	-10.7	-16.3	-17.1	-2.0
HOTEL15	-3.2	-8.1	-8.8	-1.2
HIGHS02	-5.8	-7.7	-8.2	-0.8
OFFIC03	-11.4	-10.6	-10.5	0.5
OFFIC08	-9.8	-9.5	-9.3	0.5
OFFIC16	0.5	-0.8	-0.9	-0.1
RETAIL1	-15.2	-15.1	-15.0	-0.9
RSTRNT1	-15.6	-15.5	-15.6	0.4
Average	**-9.6**	**-12.2**	**-12.4**	**-0.7**

Overall, the buildings with the greatest window-to-wall ratios realize the lowest reductions, or even increases, in energy use, energy costs, and carbon emissions while the residential buildings (apartments and dormitories), retail stores, and restaurants realize the greatest reductions.

7.1.3 Results by Climate Zone

Table 7-6 shows the nationwide average change in energy use by *ASHRAE* climate zone for the adoption of *ASHRAE 90.1-2007* relative to current state energy codes for all building types. The warmest and coldest climate zones, Zone 1 and Zone 8, realize the smallest overall percentage changes in energy use. Zone 8 realizes an increase of energy use of 1.7 % while Zone 1 realizes a small decrease of 1.1 %. Zone 2 realizes the highest reductions in energy use at 16.3 % followed by Zone 3 (12.0 %) and Zone 4 (10.4 %).

Table 7-6 Average Percentage Change in Energy Use for *ASHRAE 90.1-2007* by Climate Zone

Climate Zone/Subzone	Percentage Change 1999	2001	2004	All
1			**-1.1**	**-1.1**
2	**-24.0**		**-8.6**	**-16.3**
A	-23.9			-23.9
B	-24.2		-8.6	-13.8
3	**-19.6**	**-13.8**	**-1.9**	**-12.0**
A	-19.6	-13.8	-1.7	-12.7
B			-2.7	-2.7
4	**-14.0**	**-12.9**	**-2.5**	**-10.4**
A	-13.6	-12.9	-2.5	-10.0
B	-16.1			-16.1
5	**-14.5**	**-12.3**	**-3.5**	**-7.9**
A	-12.7	-11.2		-11.9
B	-16.2	-12.7	-3.5	-7.2
6	**-11.2**	**-10.3**	**-4.4**	**-9.7**
A	-10.6	-9.6	-4.4	-8.2
B	-11.7	-10.7		-11.4
7	**-10.5**		**-7.4**	**-9.7**
8	**1.7**			**1.7**
Grand Total	**-12.9**	**-12.3**	**-3.7**	**-9.6**

Similar to the LEC design, the current state energy codes are a key driver of these results. The variation across climate zones diverges depending on the state energy code. For locations in states that have not adopted any state energy code or have adopted older editions of *ASHRAE 90.1* (*-1999* or *-2001*), warmer climate zones realize greater percentage reductions in energy use. For states that have no state energy code or have adopted *ASHRAE 90.1-1999*, cities in Zone 2 realize an average percentage reduction of 24.0 % while Zone 8 realizes an increase of 1.7 % from adopting the *ASHRAE 90.1-2007* design. For cities located in states that have adopted *ASHRAE 90.1-2004*, the percentage reductions in energy use are much smaller, ranging from 1.1 % to 8.6 %, and do not follow the same trend where colder climate zones realize smaller reductions in energy use. Instead the percentage changes are the greatest for cities in Zone 2 followed by Zone 7 and smallest for cities in Zone 1 and Zone 3.

Table 7-7 shows that the average reduction in energy costs over a 10-year study period ranges from 1.1 % to 15.2 % depending on the climate zone. Zone 2, Zone 3, Zone 6, and Zone 7 realize reductions in energy costs over 13 %. Zone 1 realizes reductions in energy costs of only 1.1 %. The reductions in energy costs for Zone 8 of 10.2 % could be considered surprising given that Zone 8 realizes an increase in energy use.

Table 7-7 Average Percentage Change in Energy Costs for *ASHRAE 90.1-2007* by Climate Zone, 10-Year

Climate Zone/Subzone	Percentage Change			
	1999	**2001**	**2004**	**All**
1			**-1.1**	**-1.1**
2	**-24.1**		**-6.4**	**-15.2**
A	-24.1			-24.1
B	-24.1		-6.4	-12.3
3	**-21.5**	**-18.1**	**-2.9**	**-14.1**
A	-21.5	-18.1	-2.7	-14.9
B			-3.7	-3.7
4	**-17.1**	**-14.7**	**-0.9**	**-11.9**
A	-16.7	-14.7	-0.9	-11.4
B	-19.1			-19.1
5	**-18.0**	**-16.4**	**-1.4**	**-8.6**
A	-17.0	-13.0		-15.0
B	-19.0	-17.6	-1.4	-7.4
6	**-16.6**	**-17.1**	**-1.9**	**-13.8**
A	-15.9	-14.7	-1.9	-10.5
B	-17.1	-18.4		-17.5
7	**-16.5**		**-4.2**	**-13.4**
8	**-9.8**			**-9.8**
Grand Total	**-17.4**	**-16.6**	**-2.3**	**-12.1**

These results are similar to those realized for reductions in energy use in that they can be better explained after controlling for the current state energy codes. Reductions in energy use can explain some, but not all of the variation in energy costs. The remainder is a result of a shift in energy use from one energy source to another. For example, the adoption of *ASHRAE 90.1-2007* leads to a percentage change in energy use of -24.0 % and 1.7 % for cities in Zone 2 and Zone 8, respectively. Meanwhile, the percentage change in energy costs is -24.1 % and -9.8 %, respectively. The percentage change in energy use explains the entire percentage change in energy costs for cities in Zone 2. However, cities in Zone 8 realize a percentage increase in energy use and a seemingly contradictory decrease in energy costs. The adoption of *ASHRAE 90.1-2007* decreases electricity consumption, but increases natural gas consumption by a greater amount. Due to the higher cost of electricity for cities in Zone 8, energy use is increased while energy costs are decreased. Similar shifts occur for cities throughout the other climate zones, where the size of the impact depends on the size of the fuel shift and the differential between the average cost of electricity and average cost of natural gas.

Average energy-related carbon emissions are constant across study period lengths. The data reported in Table 7-8 show that the average reduction in energy-related carbon emissions for the *ASHRAE 90.1-2007* design ranges from 1.2 % to 15.3 % depending on the climate zone. Zone 1, Zone 8, and Zone 5 realize the smallest percentage reductions in carbon emissions while Zone 2 and Zone 3 realize the greatest reductions. Similar to reductions in energy costs, reductions in energy use can explain some, but not all of the variation in the reductions in carbon emissions. The remainder is a result of a shift in energy use from one energy source to another. For example, the adoption of *ASHRAE 90.1-2007* leads to a percentage change in energy use of 1.7 % and a percentage change in carbon emissions of -5.8 % for cities in Zone 8. For Alaska, the average carbon emissions rate for electricity is greater than the average carbon emissions rate for natural gas. The shift in energy use from electricity to natural gas leads to an overall decrease in carbon emissions while total energy use increases.

Table 7-8 Average Change in Energy-related Carbon Emissions for *ASHRAE 90.1-2007* by Climate Zone

Climate Zone/Subzone	Percentage Change			
	1999	2001	2004	All
1			**-1.2**	**-1.2**
2	**-24.0**		**-6.5**	**-15.3**
A	-23.8			-23.8
B	-24.1		-6.5	-12.4
3	**-22.5**	**-19.7**	**-3.2**	**-15.0**
A	-22.5	-19.7	-3.0	-15.9
B			-3.7	-3.7
4	**-18.3**	**-16.9**	**-1.0**	**-13.1**
A	-18.1	-16.9	-1.0	-12.5
B	-19.6			-19.6
5	**-18.9**	**-17.7**	**-2.1**	**-9.5**
A	-18.3	-16.8		-17.5
B	-19.5	-18.0	-2.1	-8.0
6	**-16.6**	**-17.9**	**-1.9**	**-14.0**
A	-16.3	-15.3	-1.9	-10.8
B	-17.0	-19.2		-17.6
7	**-15.6**		**-3.9**	**-12.7**
8	**-5.8**			**-5.8**
Grand Total	**-17.4**	**-18.0**	**-2.5**	**-12.4**

7.1.4 Results by State Energy Code

One purpose of this study is to determine which states could benefit the most from adopting a more stringent state energy code for commercial buildings. It would be expected that states with energy codes based on an older edition of *ASHRAE 90.1 (-2001)*, or no energy code at all, would realize greater benefits from adopting the *ASHRAE 90.1-2007* design because buildings in those states are expected to be built in a less energy efficient manner. Figure 7-1 shows the 14 states with energy codes based on *ASHRAE 90.1 -2001* or that have no state energy code.[24]

[24] All maps are generated in ArcMap 10.1.

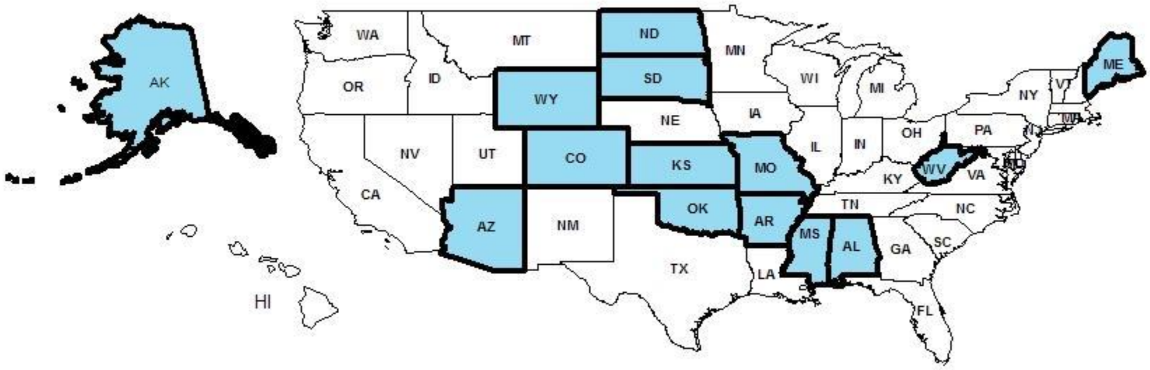

Figure 7-1 States with Energy Code based on *ASHRAE 90.1-2001* or No Energy Code

The 32 states that have adopted *ASHRAE 90.1-2007*, highlighted gray in Figure 7-2, are spread across the nation. These states are shown in white in the figures in this section, and are excluded from the analysis because there are no impacts to report.

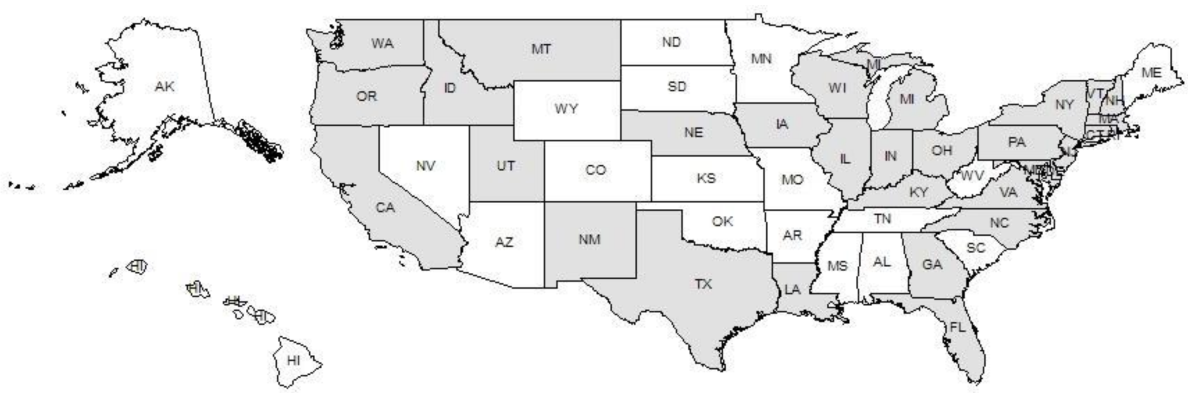

Figure 7-2 States with Energy Code based on *ASHRAE 90.1-2007* (Shown in Gray)

As in the state-by-state analysis of the LEC design, analyzing benefits from adopting the *ASHRAE 90.1-2007* design requires an assumption on the study period length because costs to maintain and operate a building fluctuate over time. A 10-year study period is used as a baseline because it is one of the most realistic investor time frames of the 9 study period length options in BIRDS.

State benefit comparisons are made based on the simple average changes for the cities analyzed in each state by building type. One building type is chosen to illustrate the detailed analysis possible with the powerful BIRDS database compiled for this study. Energy use, energy costs, cradle-to-grave energy-related carbon emissions, and life-cycle costs are analyzed for the most common existing building type, small office buildings. Summary results for the other 10 building types are reported in Table D-1 through Table D-10 in Appendix D. The same interpretations hold for the other ten building types.

Table 7-9 summarizes the percentage changes in energy use, energy costs, carbon emissions, and life-cycle costs for the 3-story office building for a 10-year study period. On average, adoption of *ASHRAE 90.1-2007* for a 3-story office building decreases energy use, energy costs, and energy-related carbon emissions by over 10 % each while increasing life-cycle costs by 0.5 %, on average. These results exclude the states that have already adopted *ASHRAE 90.1-2007*.

Table 7-9 Average Percentage Change by State, 3-Story Office Building, 10-Year

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
AK	-8.0	-10.6	-9.7	0.9
AL	-19.0	-18.3	-17.9	1.2
AR	-12.2	-13.8	-14.3	-3.4
AZ	-15.8	-14.1	-13.7	0.6
CO	-11.3	-10.9	-10.9	-2.6
HI	-1.6	-1.6	-1.6	-0.3
KS	-15.0	-14.4	-14.3	3.3
ME	-14.2	-13.8	-13.8	1.6
MN	-9.2	-4.3	-3.8	-0.5
MO	-14.8	-14.2	-13.9	3.0
MS	-26.4	-21.1	-20.9	1.7
ND	-12.5	-12.9	-13.0	2.4
NV	-5.7	-2.7	-3.5	-0.4
OK	-13.8	-15.6	-16.8	2.6
SC	-2.6	-2.4	-2.4	-0.6
SD	-12.6	-12.8	-12.8	0.8
TN	-4.6	-2.6	-2.3	-0.4
WV	-13.5	-13.1	-12.1	-2.1
WY	-13.3	-13.6	-13.6	2.2
Avg.	**-11.4**	**-10.6**	**-10.5**	**0.5**

Figure 7-3 overlays Figure 7-1 and displays the average percentage changes in energy use, energy costs, and carbon emissions for a 10-year study period by state. The states with codes based on older editions of *ASHRAE 90.1*, or no energy code at all, are shown with cross hatching and bolded state borders. The 31 states that have already adopted *ASHRAE 90.1-2007* are shown in white and are excluded from the analysis. Figure 7-3 shows that 16 of 19 states realize energy use savings greater than 5 % by adopting *ASHRAE 90.1-2007* over their current state energy code. Many of the states that realize the greatest energy use savings are the ones that currently have no energy code or energy codes based on older editions of *ASHRAE 90.1* including all 13 states that realize energy use savings of more than 10 %.

The state average percentage reductions in energy costs and carbon emissions are highly correlated with the percentage reductions in energy use. However, the reduction in energy costs and carbon emissions tend to be slightly less than the reductions in energy use. Twelve of the nineteen states realize smaller percentage changes in energy costs and carbon emissions than percentage changes in energy use. The reason for this result is because the reductions in total energy use resulting from the adoption of *ASHRAE 90.1-2007* for those twelve states are driven primarily by reductions in natural gas, as discussed in the example in Section 6.1.4.1. Since natural gas is cheaper and has a lower average emissions rate than electricity for those states, the percentage changes in energy costs and carbon emissions are smaller than the percentage changes in energy use.

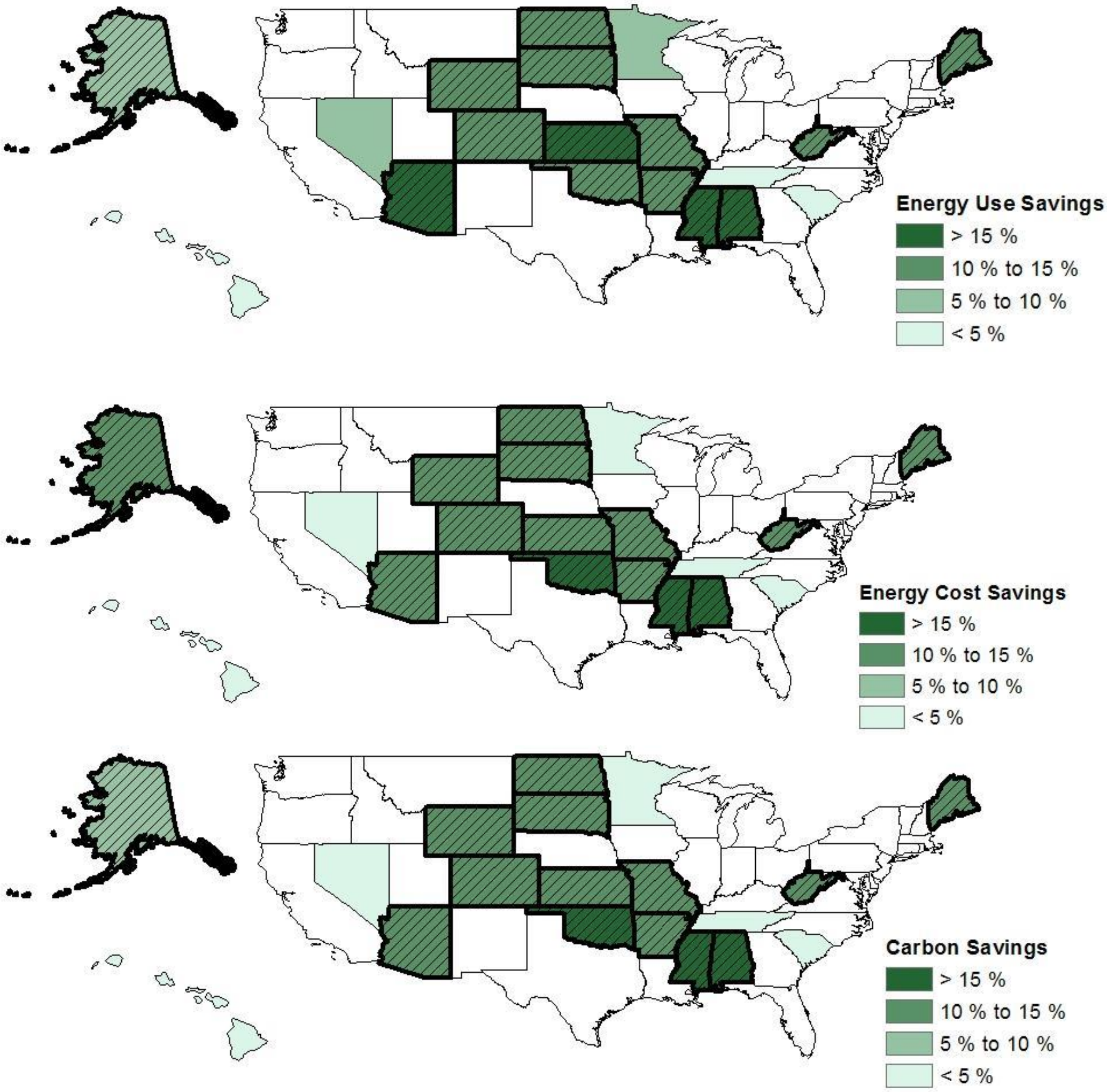

Figure 7-3 Average Energy Use Savings by State, 3-Story Office Building, 10-Year

For a 3-story office building, as expected, states that currently have no energy code or energy codes based on older editions of *ASHRAE 90.1* have the most to gain in percentage terms in energy use, energy cost, and carbon emissions savings from adopting more stringent state energy codes. However, the life-cycle cost-effectiveness of such adoptions varies across states.

Figure 7-4 overlays Figure 7-1 with the average percentage change in life-cycle costs over 10 years by state from adopting the *ASHRAE 90.1-2007* design. Of the 19 states, 8 realize an average decrease in life-cycle costs. The three states that have energy codes based on *ASHRAE 90.1-2001* realize the greatest percentage decreases in life-cycle costs (> 2 %). The five states that have adopted *ASHRAE 90.1-2004* as their state energy code realize reductions in life-cycle costs of less than 2 %. The ten states that currently have no energy code realize an average percentage increase in life-cycle costs, five of which realize an increase greater than 2 %. The additional energy efficiency measures required to bring buildings up to the *ASHRAE 90.1-2007* design from the *ASHRAE 90.1-1999* baseline design for these states add enough construction costs to offset the energy cost savings from the energy efficiency gains.

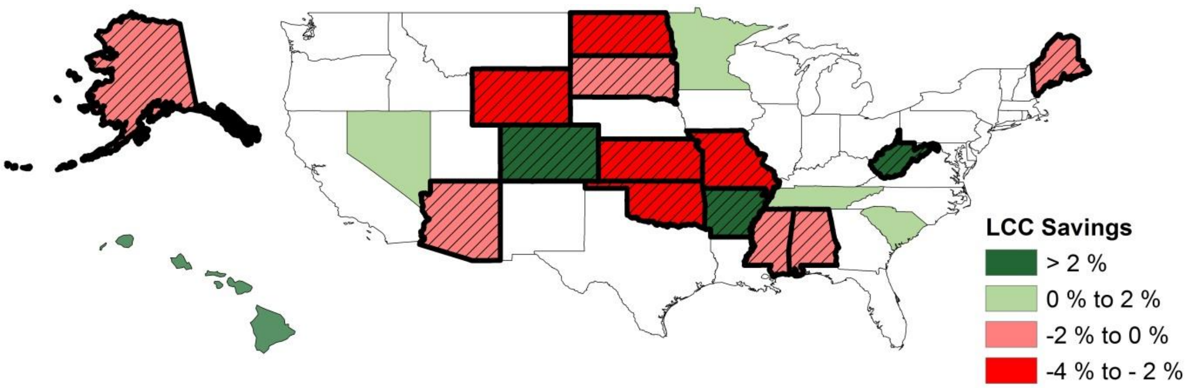

Figure 7-4 Average Life-Cycle Cost Savings by State, 3-Story Office Building, 10-Year

7.2 Total Changes

The average percentage changes in energy use, energy costs, energy-related carbon emissions, and life-cycle costs reported in Section 7.1 do not account for the amount of new floor area for each building type in a state, which may have a significant impact on the results.

7.2.1 State-Level Total Savings

Estimating the magnitude of the total impacts in a state controls for new floor area and determines which states would benefit the most from adopting the *ASHRAE 90.1-2007* design as their state energy code. The total changes in the four impacts from adopting the *ASHRAE 90.1-2007* design for a state are calculated using Formula 1 defined in Section 5.4. Based on the formula, two variables impact the magnitude of the total changes in a state: the amount of new commercial building construction and the average changes per unit of floor area.

Figure 7-5 shows the average amount of new floor area constructed annually (1000 m^2) for each of the 19 states from 2003 to 2007. States with a greater amount of new floor area constructed (Arizona, Colorado, Nevada, and Tennessee) are expected to realize greater total reductions in energy use, energy costs, and carbon emissions.

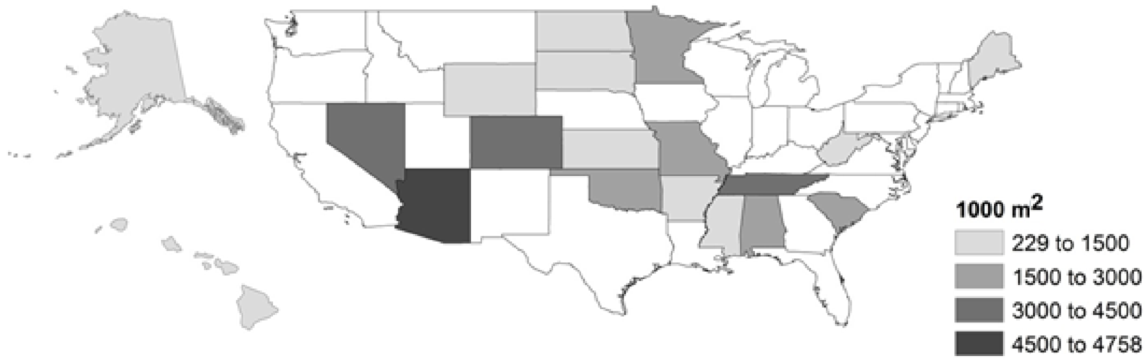

Figure 7-5 Average Annual New Floor Area by State

Table E-1 in Appendix E shows the total changes in energy use, energy costs, carbon emissions, and life-cycle costs from adopting the *ASHRAE 90.1-2007* design as the commercial building energy code for all 19 states for a 10-year study period. The relative total changes across states, shown in Figure 7-6, are significantly different than the relative percentage changes shown in Figure 7-3, which emphasizes the importance of controlling for the amount of new floor area for each building type in determining the magnitude of the impacts of adopting the *ASHRAE 90.1-2007* design. The total change in energy use for a state is driven partially by the amount of new floor area constructed in a state. Arizona realizes the greatest reductions in energy use (946 GWh). In comparison, states with the smallest amount of new floor area (Alaska, Hawaii, Maine, North Dakota, South Dakota, and Wyoming) realize savings of less than 106 GWh. However, the state energy code is also a significant driver of the results. For example, Nevada, South Carolina, and Tennessee are in the top five in total new floor area, but are not in the top ten in total energy use savings.

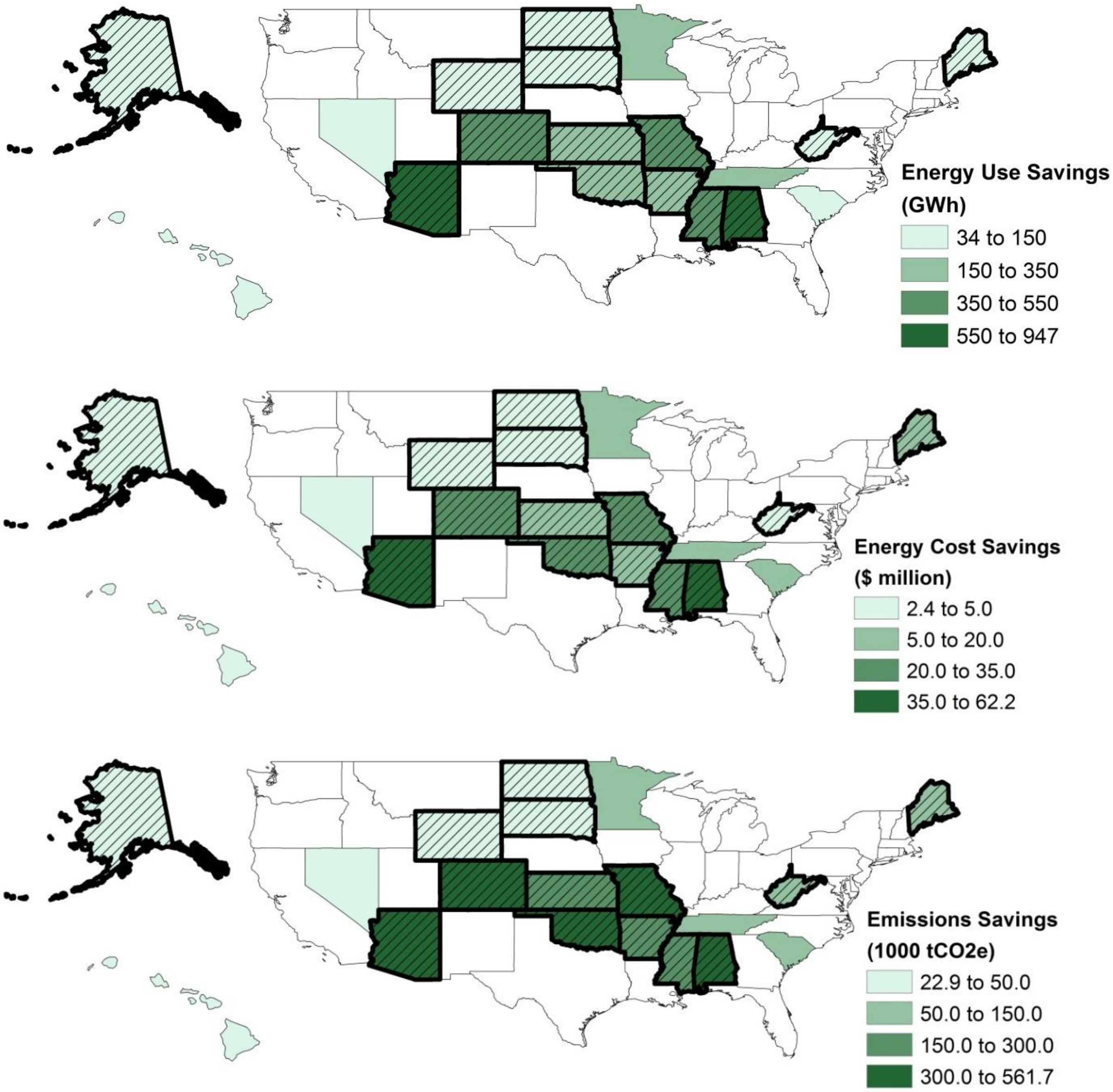

Figure 7-6 Total Energy Use, Energy Cost, and Carbon Emissions Savings by State, 10-Year

Figure 7-6 shows a correlation between total savings in energy use and total savings in energy costs and carbon emissions. Alabama, Arizona, Missouri, and Colorado realize the greatest savings while South Dakota, North Dakota, Wyoming, Nevada, Hawaii, Alaska, Maine, and South Carolina realize the smallest savings in energy costs. Arizona, Alabama, Colorado, Oklahoma, and Missouri realize the greatest reductions while South Dakota, North Dakota, Wyoming, and Nevada realize the smallest reductions in carbon emissions. The relative total reductions in energy costs and carbon emissions vary from total reductions in energy use to some extent. The reasons for this variation will be discussed in Section 7.3.

Figure 7-7 shows a correlation between total savings in energy use and total savings in life-cycle costs. Arizona, Colorado, Arkansas, and Alabama realize the greatest total life-cycle cost savings. Only two states realize an increase in life-cycle costs (Kansas and Oklahoma) while the other nine states that realize an increase in life-cycle costs on a percentage basis (see Figure 7-4) realize a total life-cycle cost decrease. These results emphasize the importance of accounting for the building types associated with the new floor area constructed in a state to determine where adopting the *ASHRAE 90.1-2007* design is life-cycle cost-effective. The relative total reductions in life-cycle costs vary from total reductions in energy use to some extent. The reasons for this variation will be discussed in Section 7.3.

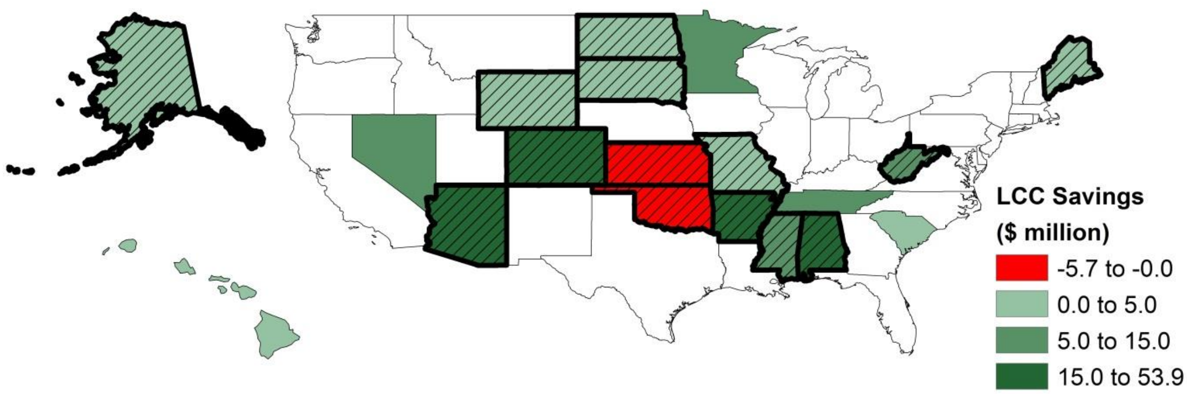

Figure 7-7 Total Life-Cycle Cost Savings by State, 10-Year

7.2.2 Regional and National Total Savings

The nationwide changes in the four impacts from adopting the *ASHRAE 90.1-2007* design are calculated using Formula 2 defined in Section 5.4, where the state-level savings for each impact are summed across all nineteen states that have not yet adopted *ASHRAE 90.1-2007*.

Table 7-10 shows the total changes in energy use, energy costs, energy-related carbon emissions, and life-cycle costs for one year's worth of construction for a 10-year study period aggregated at the Census region and national levels. The greater the amount of new floor area constructed in the states within a Census region that have not yet adopted *ASHRAE 90.1-2007*, the greater the total reduction in energy use, energy costs, and carbon emissions. This condition does not strictly hold for the total reduction in life-cycle costs because the total reduction in the West Census Region is greater than total reduction in the South Census Region. The reason for this variation will be discussed in Section 7.3. The nationwide reductions total 4.9 TWh in energy consumption, \$312.4 million in energy costs, 3.8 million metric tons in energy-related carbon emissions, and \$173.3 million in life-cycle costs for the 10-year study period.

Table 7-10 Total Reductions by Census Region from Adoption of the *ASHRAE 90.1-2007* Design, 10-Year

Census Region	Number of States	Average Annual New Floor Area 1000 m^2 (1000 ft^2)	Energy Use (GWh)	Energy Costs ($million)	Carbon (1000 tCO_2e)	LCC ($million)
Northeast	1	497 (5349)	105.5	9.4	58.8	3.3
Midwest	5	6296 (67 767)	1139.5	54.5	867.1	7.7
South	7	12 750 (137 243)	1968.2	139.4	1707.2	67.4
West	6	12 622 (135 861)	1667.6	109.1	1183.4	94.9
Total	**19**	**32 165 (346 220)**	**4880.8**	**312.4**	**3816.5**	**173.3**

7.3 Changes per Unit of Floor Area and Energy Use Savings

Total savings in energy use, energy costs, carbon emissions, and life-cycle costs are correlated. However, there are a number of factors that lead to significant variation in relative savings, each of which will be discussed in this section.

7.3.1 State Level Changes

There is significant variation in relative savings across states for each of the four impacts for a number of reasons, including current state energy code requirements, newly constructed building stock mix and size, climate zone, electricity costs, electricity production fuel mix (average emissions rate), and the relative percentage changes in fuel types consumed by the building.

7.3.1.1 Energy Use Savings per Unit of Floor Area

Total energy use savings varies across states for a number of reasons. First, states with more newly constructed commercial floor area realize greater reductions in energy use. Second, states located in warmer climate zones tend to realize greater reductions in energy use than the states located in colder climate zones. Third, a state's current state energy code for commercial buildings drives variation in energy use.

Table E-2 shows the 10-year reduction in energy use per unit of newly constructed floor area sorted by energy savings per unit of new floor area in descending order. The reduction in energy use per unit of floor area is primarily driven by the state's adopted energy code for commercial buildings. The top thirteen states with the greatest per unit reduction from adoption of the *ASHRAE 90.1-2007* design have no state energy code or have *ASHRAE 90.1-2001* as their state energy code. These results, shown in Figure 7-8, can be compared to the average percentage changes in energy use in Figure 7-3. After controlling for the amount of new floor area, the relative savings across states correlates much closer to the relative average percentage changes in energy use. However, the correlation is not perfect because the total changes weight building types based on new floor area constructed.

Figure 7-8 Energy Use Savings per Unit of Floor Area by State, 10-Year

7.3.1.2 Life-Cycle Cost Savings per Unit of Floor Area

The relative change in life-cycle costs per unit of new floor area is shown in Table E-3. After controlling for the amount of new floor area, there is a correlation between the state energy code and the relative life-cycle cost savings of adopting the *ASHRAE 90.1-2007* design. States that have adopted *ASHRAE 90.1-2001* (Arkansas, Colorado, and West Virginia) realize the greatest life-cycle cost savings. These results, shown in Figure 7-9, can be compared to the average percentage changes in life-cycle costs in Figure 7-4. After controlling for the amount of new floor area, the relative savings across states correlates better with the relative percentage changes in energy use. However, the correlation is not perfect because the total changes weight building types based on new floor area constructed.

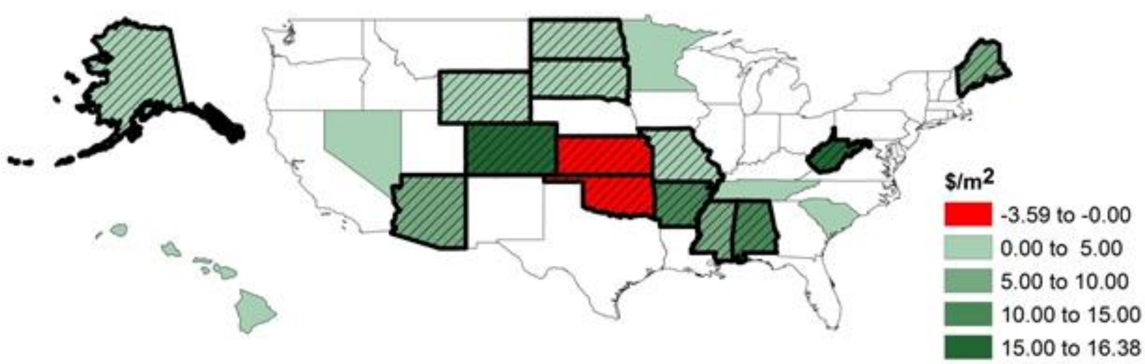

Figure 7-9 Life-Cycle Cost Savings per Unit of Floor Area by State, 10-Yr

7.3.1.3 Energy Cost Savings per Unit of Energy Use Savings

In general, the states that realize the greatest reductions in energy use also realize the greatest reductions in energy costs. However, reductions in energy costs are also impacted by the per unit costs of electricity and natural gas and the fuel mix of the reductions in total energy use in a state. Table E-4 shows each state's reduction in energy costs per unit of reduction in energy use, natural gas rate, electricity rate, and the fraction of electricity consumption reductions offset by increases in natural gas consumption.[25] States with the highest electricity rates tend to realize the greatest reductions in energy costs per unit of reduction in energy use. Relative to electricity prices, natural gas has minimal impacts on the relative reduction because natural gas prices are fairly constant across states (excluding Hawaii) and are significantly cheaper per unit of energy for all nineteen states.

The correlation between a state's average electricity price and the savings in energy costs per unit of energy use savings is shown in Figure 7-10. States with the highest electricity prices (Alaska, Hawaii, and Maine) realize the greatest savings in energy costs per unit of savings in energy use.

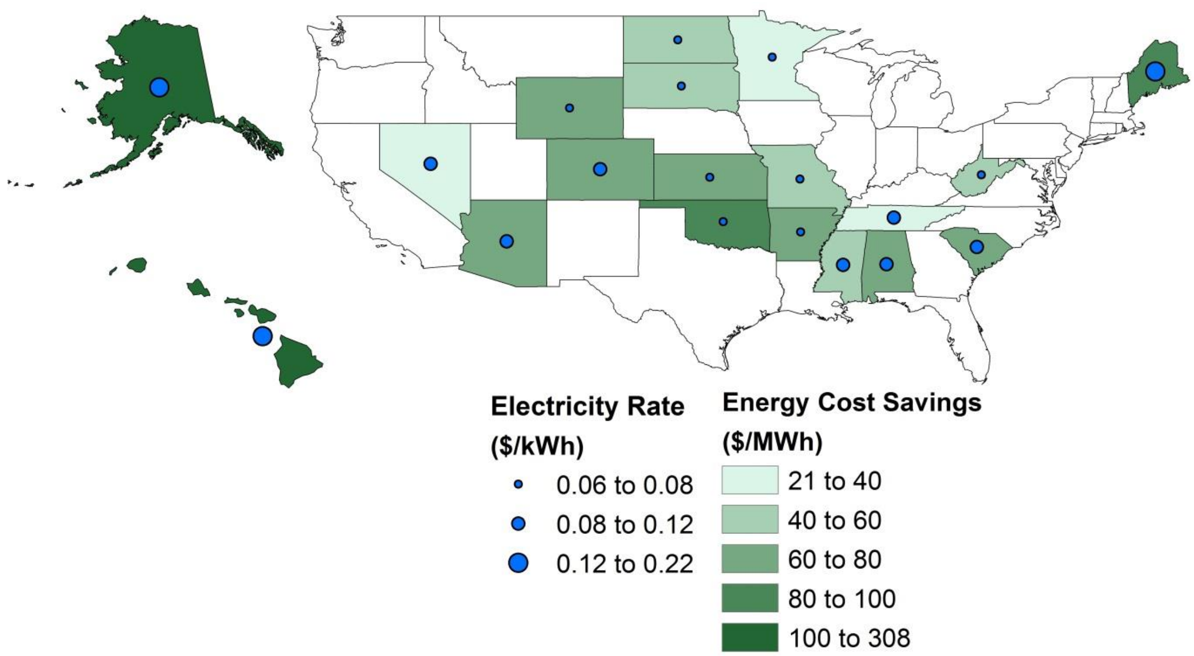

Figure 7-10 Energy Cost Savings per Unit of Energy Use Savings and Average Electricity Price by State

[25] The fraction of electricity offset by natural gas consumption is greater than 100 % when natural gas consumption increases by a greater amount than electricity consumption decreases. The fraction of electricity offset by natural gas consumption is less than -100 % when natural gas consumption increases (decreases) by a greater amount than electricity consumption decreases. For some states (e.g. Minnesota) the magnitude of the offset is large because the change in electricity is minimal, leading to the change in natural gas to be large in comparison on a percentage change basis.

The electricity price does not explain all the variation across states in energy cost savings per unit of energy use savings because there are two sources of energy cost savings: the energy costs savings from total energy use reduction, and the energy cost savings from the shift of fuel consumption from more expensive electricity to cheaper natural gas. The savings from the shift in fuels is a result of two factors: the energy cost savings per unit of energy shifted from electricity to natural gas consumption (energy price differential) and the amount of energy shifted from electricity to natural gas consumption. The energy cost savings increases as the energy price differential increases because the cost savings for each unit of electricity "offset" by a unit of natural gas is greater. The greater the fraction of electricity consumption shifted to natural gas consumption, or offset, the greater the energy cost savings per unit of total energy use savings.

The metric used to explain the shift in fuel consumption is the "weighted average offset," which is the average percentage offset weighted by the amount of new floor area for each building type in a state. Figure 7-11 shows the weighted average offset for each state, with twelve of nineteen states realizing a negative offset.

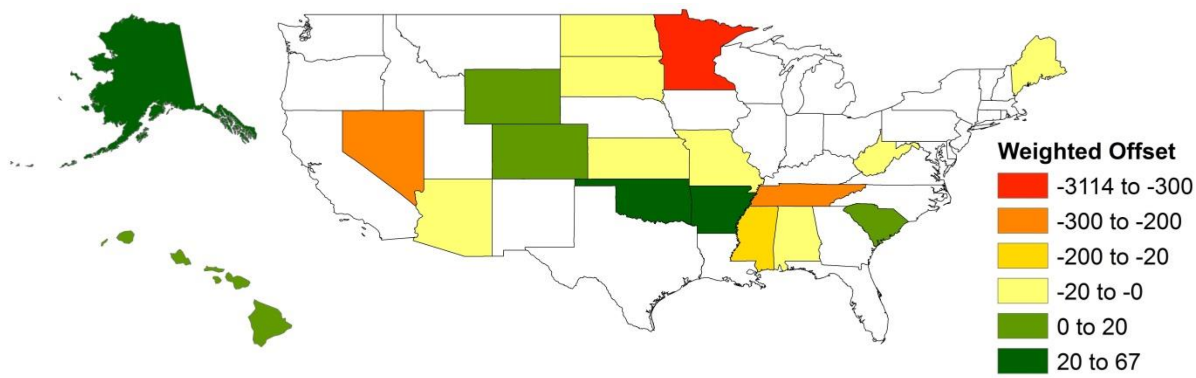

Figure 7-11 Weighted Average Offset by State

Figure 7-12 shows the savings in energy costs per unit of savings in energy use ($/MWh) based on the price differential between electricity and natural gas ($/kWh) and the weighted average offset (%) for each state. States with a greater energy price differential combined with a greater weighted average offset realize the greatest energy cost savings per unit of energy use savings.

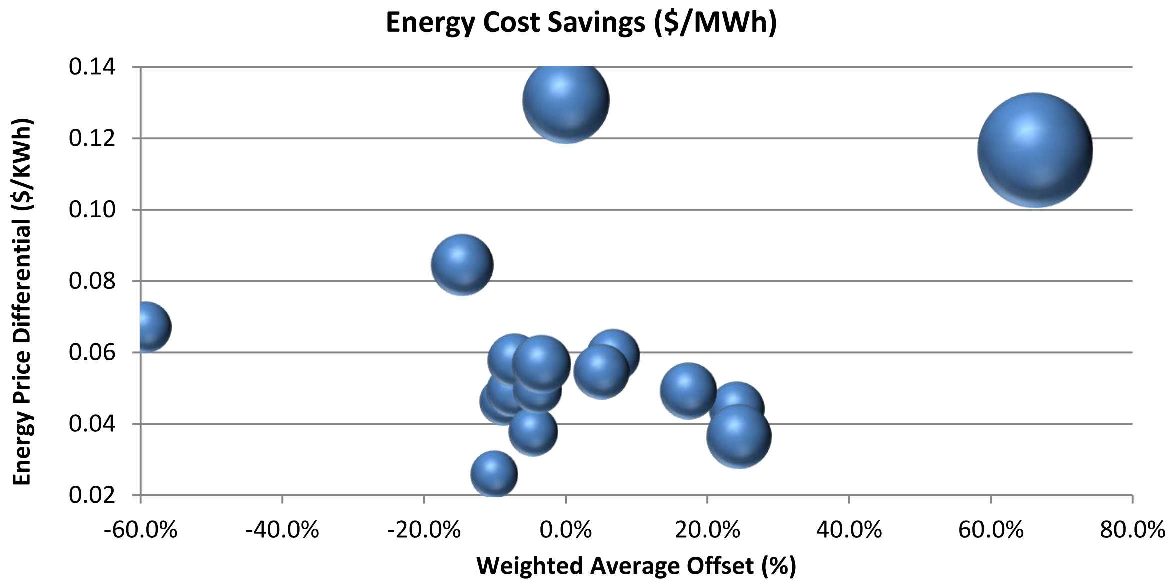

Figure 7-12 Average State Energy Cost Savings per Unit of Energy Use Savings by Weighted Average Offset and Energy Price Differential

7.3.1.4 Carbon Emissions Savings per Unit of Energy Use Savings

In general, the states that realize the greatest reductions in energy use also realize the greatest reductions in energy-related carbon emissions. However, reductions in energy costs are also impacted by the per unit energy costs of electricity and natural gas and the fuel mix of the reductions in energy use in a state. Table E-5 shows the weighted average fraction of electricity consumption offset by a change in natural gas consumption, the average CO_2 emissions rates for electricity and natural gas, and the reduction in cradle-to-grave energy-related carbon emissions per unit of reduction in energy use for the nineteen states in this study. States with the highest emissions rates for electricity generation tend to realize the greatest reductions in carbon emissions per unit of reduction in energy use. Relative to electricity emissions rates, natural gas has minimal impact on the relative reduction because natural gas emissions rates are constant across states and are significantly lower per unit of energy for all nineteen states.

The correlation between a state's average electricity emissions rate and the savings in energy-related emissions per unit of energy reduced is shown in Figure 7-13. States in the central U.S. and West Virginia have the highest average electricity emissions rates and tend to realize the greatest savings in carbon emissions per unit of savings in energy use. Meanwhile, states with the lowest average electricity emissions rates (e.g., Nevada) realize the smallest carbon emissions savings per unit of energy use savings.

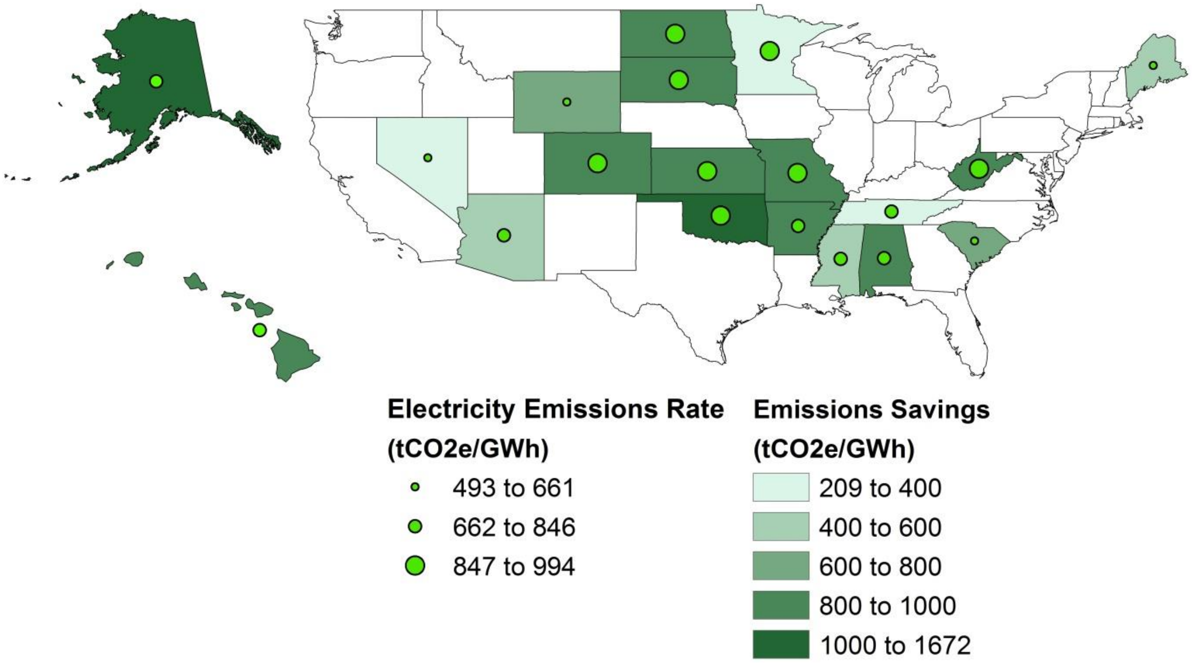

Figure 7-13 Energy-related Carbon Emissions Savings per Unit of Energy Use Savings and Average Electricity Emissions Rate by State

The electricity emissions rate does not explain all the variation across states in energy-related carbon emissions savings per unit of energy use savings because there are two sources of carbon emission savings: the carbon emissions savings from total energy use reduction, and the carbon emissions savings from the shifting of fuel consumption from the more carbon intensive electricity to less carbon intensive natural gas. The carbon emissions savings increase as the emissions rate differential increases because the carbon emissions savings for each unit of electricity "offset" by a unit of natural gas is greater. The greater the fraction of electricity consumption reductions offset by increases in natural gas consumption, the greater the carbon emissions savings per unit of energy use savings.

Figure 7-14 shows the savings in carbon emissions per unit of savings in energy use (tCO_2e/GWh) based on the emissions rate differential between electricity and natural gas (tCO_2e/GWh) and the weighted average offset (%) for each state. States with a greater carbon emissions rate differential combined with a greater weighted average offset realize the greatest carbon emissions savings per unit of energy use savings.

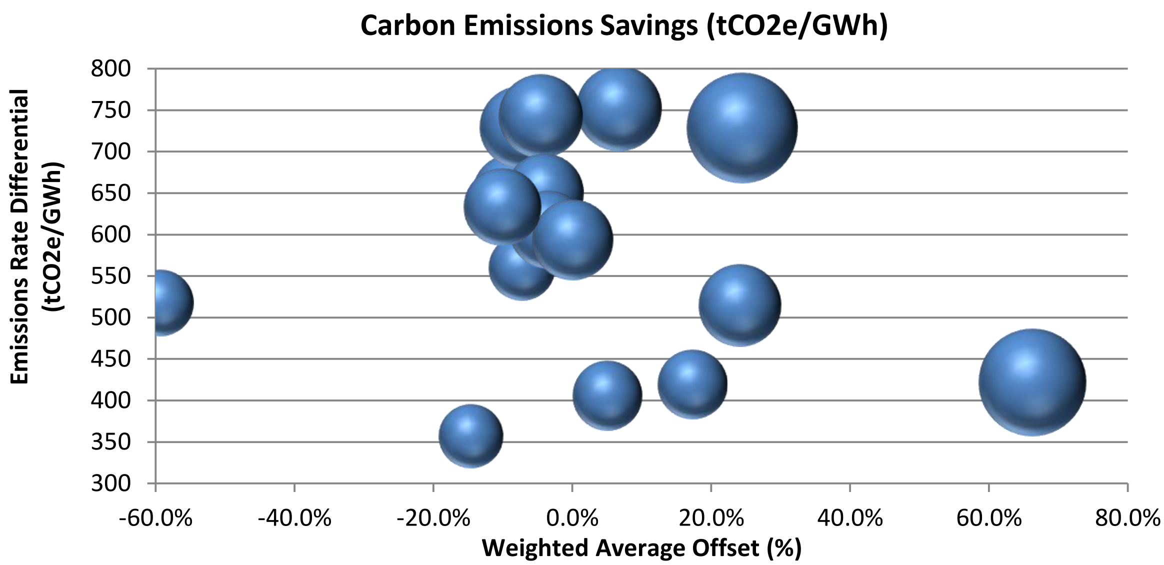

Figure 7-14 Average State Carbon Emissions Savings per Unit of Energy Use by Weighted Average Offset and Energy Emissions Rate Differential

7.3.2 Regional and National Level Changes

Table 7-11 shows the reduction in energy use per unit of newly constructed floor area from adopting the *ASHRAE 90.1-2007* design by Census region. The only state in the Northeast Census Region (Maine) realizes the greatest reduction while states in the West Census Region realize the smallest reduction in energy use per unit of floor area. The nationwide weighted average reduction in energy use per unit of floor area is 152 kWh/m^2 (14 kWh/ft^2). The variation across Census regions is a result of a number of factors, including a location's energy code and climate zone.

Table 7-11 Energy Use Reduction per Unit of Floor Area for Adoption of the *ASHRAE 90.1-2007* Design by Census Region, 10-Year

State	Average Annual New Floor Area 1000 m^2 (1000 ft^2)	Energy Use (GWh)	kWh/m^2	kWh/ft^2
Northeast	497 (5349)	106	212	20
Midwest	6296 (67 767)	1140	181	17
South	12 750 (137 243)	1968	154	14
West	12 622 (135 861)	1668	132	12
Total	**32 165 (346 220)**	**4881**	**152**	**14**

Table 7-12 shows each Census Region's natural gas rate, electricity rate, weighted average fraction of the reduction in electricity consumption offset by the change in natural gas consumption, and average reduction in energy costs from adopting the *ASHRAE 90.1-2007* design. The Northeast Census Region has the highest average electricity rate, and realizes the greatest reductions in energy costs per unit of reduction in energy use. Meanwhile, the Midwest Census Region has the smallest average electricity rate, and realizes the smallest reductions in energy costs per unit of reduction in energy use.

Table 7-12 Energy Cost Reduction per kWh of Energy Use Reduction for Adoption of the *ASHRAE 90.1-2007* Design by Census Region, 10-Year

State	Offset* (%)	Electricity Rate* ($/kWh)	Natural Gas Rate* ($/kWh)	Energy Cost Reduction ($/kWh)
Northeast	-15	0.13	0.04	0.09
South	-69	0.09	0.04	0.07
West	-66	0.09	0.03	0.07
Midwest	-1123	0.07	0.03	0.06
Total	**-276**	**0.09**	**0.03**	**0.06**
*Weighted by energy use savings for a state				

Table 7-13 shows each Census Region's natural gas emissions rate, electricity emissions rate, weighted average fraction of the reduction in electricity consumption offset by the change in natural gas consumption, and average reduction in carbon emissions from adopting the *ASHRAE 90.1-2007* design. The only state in the Northeast Census Region (Maine) has the lowest average electricity emissions rate, and realizes the smallest reductions in carbon emissions per unit of reduction in energy use. Even though the South Census Region does not have the largest average electricity emissions rate, it realizes the greatest reductions in carbon emissions per unit of reduction in energy use. This is because it has a greater (smaller negative) offset than the Midwest Census Region, leading to the South realizing greater carbon emissions savings per unit of energy use savings.

Table 7-13 Carbon Reduction per GWh of Energy Use Reduction for Adoption of the *ASHRAE 90.1-2007* Design by Census Region, 10-Year

State	Offset* (%)	CO_2e Emissions Rate for Electricity* (t/GWh)	CO_2e Emissions Rate for Natural Gas (t/GWh)	CO_2e Reduction (t/GWh)
South	-69	825	241	867
Midwest	-1123	950	241	761
West	-66	838	241	710
Northeast	-15	599	241	557
Total	**-276**	**854**	**241**	**774**
*Weighted by energy use savings for a state				

Table 7-14 shows the average life-cycle cost reduction per unit of new floor area by Census Region. The combination of greater energy use savings per unit of floor area and higher electricity rates tends to lead to greater life-cycle cost savings from adopting the *ASHRAE 90.1-2007* design. The Census regions with the lowest electricity rate (Midwest) and the smallest energy use savings per unit of floor area (South) realize the lowest and 2nd-lowest life-cycle cost savings per unit of floor area, respectively. The West Census Region realizes greater life-cycle cost savings per unit of floor area than the Northeast Census Region, which may be driven by a number of factors, including baseline energy codes and local construction costs across the two regions.

Table 7-14 Life-Cycle Cost Reductions per Unit of New Floor Area for Adoption of the *ASHRAE 90.1-2007* Design by Census Region, 10-Year

State	Energy Use Savings (kWh/m^2)	Electricity Rate* ($/kWh)	LCC Savings ($million)	LCC Savings ($\$/m^2$)	LCC Savings ($\$/ft^2$)
West	132	0.09	94.9	7.52	0.70
Northeast	212	0.13	3.3	6.64	0.62
South	154	0.09	67.4	5.29	0.49
Midwest	181	0.07	7.7	1.22	0.11
Total	**156**	**0.09**	**173.3**	**5.39**	**0.50**

8 Incremental Impacts from Adopting More Stringent Standard Editions

This chapter estimates the incremental changes for a state adopting a more recent edition of *ASHRAE 90.1* or the LEC design. Section 8.1 will consider incremental impacts on energy use at the state level. Section 8.2 will consider the incremental impacts on life-cycle costs at the state level. The analysis focuses on the nineteen states that have not yet adopted *ASHRAE 90.1-2007*.

8.1 Energy Use Savings

In order to determine the incremental impacts of the adoption of more recent standard editions (a.k.a. impact from adopting the next edition), it is necessary to compare the total savings from adopting each design alternative for the 19 states analyzed in Chapter 7.

Table 8-1 shows the incremental change in total energy use (GWh) by state from adopting the next edition of *ASHRAE 90.1*. The incremental impact from adopting *ASHRAE 90.1-2001* is marginal relative to the more recent editions of *ASHRAE 90.1* or the LEC design. The adoption of *ASHRAE 90.1-2007* tends to realize a smaller increment in savings than adoption of the *ASHRAE 90.1-2004* or LEC designs.

Table 8-1 Incremental Change in Energy Use by State and Building Design, 10-Year

State	Code	Incremental Change in Energy Use (GWh)			
		ASHRAE 90.1-2001	***ASHRAE 90.1-2004***	***ASHRAE 90.1-2007***	**Low Energy Case**
AK	None	1.1	-3.0	15.8	85.4
ND	None	3.2	9.7	32.7	58.9
WY	None	2.7	19.4	12.9	41.7
SD	None	3.4	25.6	28.5	64.8
ME	None	5.6	41.3	58.5	111.2
OK	None	38.1	220.6	41.7	297.6
KS	None	23.4	122.2	83.8	209.1
MO	None	35.3	309.8	178.9	460.6
AL	None	48.9	469.5	113.2	419.0
MS	None	34.3	302.5	133.8	218.9
AZ*	None		449.2	497.1	911.2
AR	2001		173.6	30.7	221.8
CO	2001		308.8	234.1	570.0
WV	2001		58.7	37.7	80.7
HI	2004			12.1	126.3
SC	2004			92.2	502.3
NV	2004			117.3	591.7
TN	2004			172.6	635.2
MN	2004			282.7	534.0
Total		196.0	2507.9	2176.3	6140.4

*Excludes incremental changes from adopting *ASHRAE 90.1-2001* because three cities in Arizona have adopted *ASHRAE 90.1-2004*.

Incremental change comparisons across states are not possible because the amount of new floor area varies across states. To control for this, Table 8-2 shows the reduction in energy use per unit of new floor area for each building design. On average, going beyond *ASHRAE 90.1-2007* and adopting the LEC design leads to the greatest reductions (202 kWh/m^2 (19 kWh/ft^2)) followed by the incremental reductions from adopting *ASHRAE 90.1-2004* (112 kWh/m^2 (11 kWh/ft^2)), *ASHRAE 90.1-2007* (71 kWh/m^2 (7 kWh/ft^2)), and *ASHRAE 90.1-2001* (16 kWh/m^2 (1 kWh/ft^2)).

Table 8-2 Change in Energy Use per Unit of Floor Area by State and Building Design, 10-Year

State	Code	Energy Use Savings per Unit of Floor Area							
		ASHRAE 90.1-2001		***ASHRAE 90.1-2004***		***ASHRAE 90.1-2007***		**Low Energy Case**	
		kWh/m^2	**kWh/ft^2**	**kWh/m^2**	**kWh/ft^2**	**kWh/ft^2**	**kWh/ft^2**	**kWh/m^2**	**kWh/ft^2**
AK	None	4	0	-10	-1	54	5	294	27
AL	None	22	2	208	19	50	5	186	17
KS	None	22	2	113	11	78	7	194	18
ME	None	11	1	83	8	118	11	224	21
MO	None	15	1	131	12	76	7	195	18
MS	None	27	3	242	22	107	10	175	16
ND	None	14	1	42	4	143	13	257	24
OK	None	24	2	139	13	26	2	187	17
SD	None	11	1	84	8	94	9	214	20
WY	None	12	1	84	8	56	5	181	17
AZ*	None			94	9	104	10	192	18
AR	2001			146	14	26	2	187	17
CO	2001			94	9	71	7	173	16
WV	2001			123	11	79	7	168	16
HI	2004					23	2	236	22
MN	2004					121	11	229	21
NV	2004					33	3	168	16
SC	2004					34	3	185	17
TN	2004					53	5	194	18
Average		16	1	112	11	71	7	202	19

*Excludes incremental changes from adopting *ASHRAE 90.1-2001* because three cities in Arizona have adopted *ASHRAE 90.1-2004*.

Figure 8-1 shows the incremental energy use savings for each energy standard edition as a fraction of the sum of the positive incremental savings in energy use. For a standard edition that increases energy use (e.g., *ASHRAE 90.1-2004* for Alaska), the impact is estimated as a negative fraction of the total savings from the editions that increase energy use savings (e.g., the *ASHRAE 90.1-2001*, *ASHRAE 90.1-2007*, and LEC designs for Alaska).

The states that have already adopted *ASHRAE 90.1-2004* realize a greater share of their savings from the LEC design (65.4 % to 91.3 %) because the difference between *ASHRAE 90.1-2004* and *ASHRAE 90.1-2007* design requirements are minimal relative to the additional energy efficiency requirements for the LEC design. For states that have no state energy code or have adopted *ASHRAE 90.1-2001*, the LEC design accounts for 31.8 % to 56.3 % while the *ASHRAE 90.1-2004* design accounts for -2.9 % to 44.7 % of the energy use savings. The *ASHRAE 90.1-2004* design accounts for a greater percentage of energy use savings than the *ASHRAE 90.1-2007* design for 9 of 14 states. There are minimal impacts from adopting *ASHRAE 90.1-2001* because there are few differences in energy efficiency requirements relative to *ASHRAE 90.1-1999*.

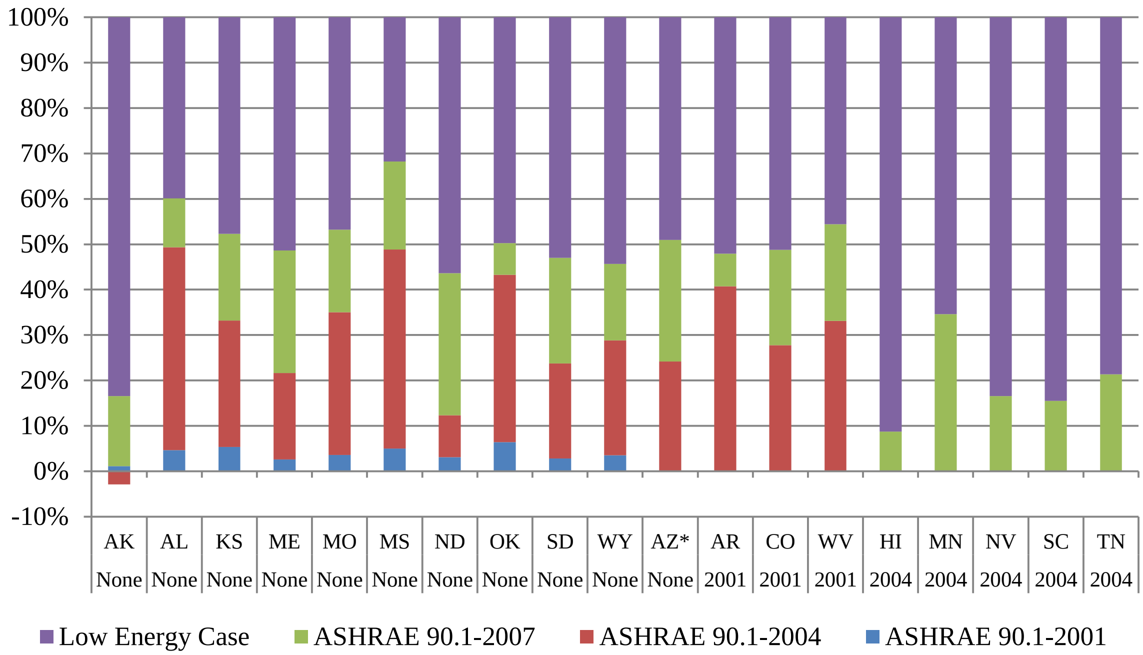

Figure 8-1 Incremental Energy Use Savings by State and Standard Edition

Since energy costs and energy-related carbon emissions are highly correlated with energy use, the same trends and interpretations hold for the incremental changes in energy costs and carbon emissions. Variation from energy use is due to a state's energy prices, energy emissions rates, and the relative changes in energy use for electricity and natural gas consumption discussed in Section 6.2 and Section 7.2.

8.2 Life-Cycle Cost Savings

In order to determine the incremental life-cycle cost impacts of the adoption of more recent standard editions, it is necessary to compare the total life-cycle costs from adopting each design alternative for the 19 states analyzed in Chapter 7.

Table 8-3 shows the incremental change in life-cycle cost savings ($ million) by state and building design. Adopting *ASHRAE 90.1-2001* can lead to significant increases in life-cycle costs ($2.9 million to $37.3 million) for all states, which is a result of the high-cost HVAC efficiency requirement increases relative to *ASHRAE 90.1-1999*. Adopting *ASHRAE 90.1-2004* can lead to significant decreases in life-cycle costs relative to *ASHRAE 90.1-2001* ($3.6 million to $91.1 million) for all nine states and offsets most, if not all of the additional life-cycle costs from adopting *ASHRAE 90.1-1999*. Five of the nine states with no state energy code realize a net decrease in life-cycle costs from adopting *ASHRAE 90.1-2004*.[26] The adoption of the *ASHRAE 90.1-2007* design realize much smaller savings relative to *ASHRAE 90.1-2004* (-$0.2 million to $46.6 million). The adoption of the LEC design realizes similar incremental savings relative to *ASHRAE 90.1-2007* (-$0.2 million to $48.3 million). At the margin, adopting the *ASHRAE 90.1-2007* and LEC designs increase life-cycle costs for two states (Oklahoma and Arkansas) and one state (West Virginia), respectively.

Table 8-3 Incremental Change in Life-Cycle Cost Reductions by State and Building Design, 10-Year

State	Code	Incremental Change in Life-Cycle Cost Savings ($ million)			
		ASHRAE 90.1-2001	***ASHRAE 90.1-2004***	***ASHRAE 90.1-2007***	**Low Energy Case**
AK	None	-3.8	4.6	0.6	0.9
AL	None	-30.1	48.7	7.2	11.3
KS	None	-22.3	15.4	3.9	5.2
ME	None	-7.9	9.2	1.9	3.1
MO	None	-37.3	32.2	7.0	0.8
MS	None	-21.4	26.7	7.0	2.5
ND	None	-3.4	2.6	0.8	0.0
OK	None	-26.2	20.6	-0.2	6.4
SD	None	-2.9	3.6	0.7	0.9
WY	None	-3.9	3.7	0.7	0.2
AZ*	None		91.1	46.6	48.3
AR	2001		17.7	-0.1	2.8
CO	2001		46.1	7.8	5.8
WV	2001		5.6	1.8	-0.2
HI	2004			2.0	11.9
MN	2004			7.3	5.1
NV	2004			6.3	11.6
SC	2004			2.9	9.3
TN	2004			7.5	20.6
Total		-159.2	327.8	111.7	146.5

*Excludes incremental changes from adopting *ASHRAE 90.1-2001* because three cities in Arizona have adopted *ASHRAE 90.1-2004*.

Incremental change comparisons across states are not possible because the amount of new floor area varies across states. Table 8-4 shows the reduction in life-cycle costs per unit of new floor area for each building design. On average, adopting the *ASHRAE 90.1-*

[26] Excluding Arizona.

2004 design leads to the greatest marginal reductions (\$15.52/m^2 (\$1.44/ft^2)) followed by the LEC design (\$4.24/m^2 (\$0.39/ft^2)), *ASHRAE 90.1-2007* (\$3.04/m^2 (\$0.28/ft^2)), and *ASHRAE 90.1-2001* (-\$15.39/m^2 (-\$1.43/ft^2)). There is significant variation in incremental life-cycle cost savings per unit of floor area within each building design.

Table 8-4 Incremental Change in Life-Cycle Cost Reductions per Unit of New Floor Area by State and Building Design, 10-Year

State	Code	Incremental Change in Life-cycle Cost Savings per Unit of Floor Area							
		ASHRAE 90.1-2001		***ASHRAE 90.1-2004***		***ASHRAE 90.1-2007***		**Low Energy Case**	
		\$/m2	**\$/ft2**	**\$/m2**	**\$/ft2**	**\$/m2**	**\$/ft2**	**\$/m2**	**\$/ft2**
AK	None	-13.10	-1.22	15.86	1.48	2.07	0.19	3.10	0.29
--AL	None	-13.35	-1.24	21.61	2.01	3.19	0.30	5.01	0.47
KS	None	-20.71	-1.92	14.30	1.33	3.62	0.34	4.83	0.45
ME	None	-15.90	-1.48	18.51	1.72	3.82	0.36	6.24	0.58
MO	None	-15.82	-1.47	13.66	1.27	2.97	0.28	0.34	0.03
MS	None	-17.11	-1.59	21.34	1.98	5.60	0.52	2.00	0.19
ND	None	-14.85	-1.38	11.35	1.06	3.49	0.32	0.00	0.00
OK	None	-16.48	-1.53	12.96	1.20	-0.13	-0.01	4.03	0.37
SD	None	-9.57	-0.89	11.88	1.10	2.31	0.21	2.97	0.28
WY	None	-16.96	-1.57	16.09	1.49	3.04	0.28	0.87	0.08
AZ*	None			19.15	1.78	9.79	0.91	10.15	0.94
AR	2001			14.92	1.39	-0.08	-0.01	2.36	0.22
CO	2001			14.00	1.30	2.37	0.22	1.76	0.16
WV	2001			11.69	1.09	3.76	0.35	-0.42	-0.04
HI	2004					3.73	0.35	22.20	2.06
MN	2004					3.13	0.29	2.19	0.20
NV	2004					1.79	0.17	3.30	0.31
SC	2004					1.07	0.10	3.42	0.32
TN	2004					2.29	0.21	6.30	0.58
Average		-15.39	-1.43	15.52	1.44	3.04	0.28	4.24	0.39

*Excludes incremental changes from adopting *ASHRAE 90.1-2001* because three cities in Arizona have adopted *ASHRAE 90.1-2004*.

Figure 8-2 shows the incremental life-cycle cost savings for each energy standard edition as a fraction of the sum of the positive incremental savings in life-cycle costs. For a standard edition that increases life-cycle costs (e.g., *ASHRAE 90.1-2001*), the impact is estimated as a negative fraction of the total savings from the editions that increase life-cycle cost savings (e.g., the *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, and LEC designs).

The fraction of the life-cycle cost savings resulting from adopting the LEC design varies across states that have already adopted *ASHRAE 90.1-2004* (41.1 % to 85.6 %). For states that have no state energy code or have adopted *ASHRAE 90.1-2001*, the *ASHRAE 90.1-2004* design accounts for 49.0 % to 86.3 % while the *ASHRAE 90.1-2007* design accounts for -0.7 % to 58.9 % of the life-cycle cost savings. The *ASHRAE 90.1-2004* design accounts for the greatest percentage of life-cycle cost savings (49.0 % to 86.3 %). There are significant negative impacts from adopting *ASHRAE 90.1-2001*, which offset 44.8 % to 100.0 % of life-cycle cost savings from adopting the *ASHRAE 90.1-2004*, *ASHRAE 90.1-2007*, and LEC designs.

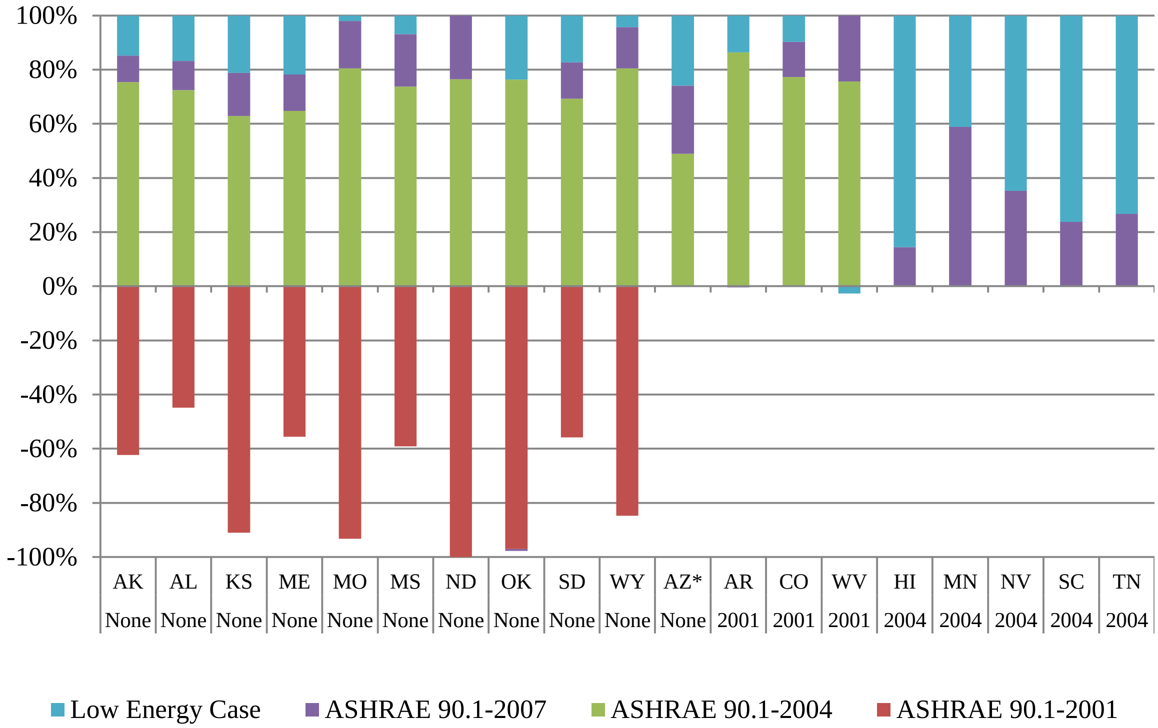

Figure 8-2 Incremental Life-cycle Cost Savings by State and Building Design

9 Discussion

This study analyzes the impacts of adopting new, more stringent state energy codes based on the BIRDS database for 11 prototypical building types in 228 U.S. locations. Results are summarized at the state, regional, and national levels. This section will discuss key findings, limitations of the research, and recommended directions for future research.

9.1 Key Findings

The key findings from this study are described for each metric used for the analysis: percentage change, total change, and change per unit of floor area. Additionally, incremental changes, both in aggregate and per unit of floor area, will be discussed.

9.1.1 Percentage Changes

Overall, adoption of *ASHRAE 90.1-2007* for the 19 states that have not yet adopted it as their state energy code leads to percentage reductions in energy use, energy costs, and energy-related carbon emissions. The average percentage reduction in energy use for new commercial buildings is 9.6 % while energy costs and carbon emissions realize average reductions of 12.2 % and 12.4 %, respectively. The reductions in energy use and carbon emissions are cost-effective, with average life-cycle costs decreasing by 0.7 % over a 10-year study period.

However, *ASHRAE 90.1-2007* does not lead to energy efficiency improvements over older editions of *ASHRAE 90.1* for all locations in the U.S. for two reasons. First, the simplification of the *ASHRAE* climate zones from 26 zones in *ASHRAE 90.1-2001* to eight zones in *ASHRAE 90.1-2004* resulted in the relaxation of some building envelope requirements for some locations. Second, *ASHRAE 90.1-2007* has less stringent solar heat gain coefficient (SHGC) requirements relative to *ASHRAE 90.1-2004* for some climate zones. As a result, high-rise, 100 % glazed buildings realize smaller reductions, and occasionally increases, in energy use because the less stringent window requirements overwhelm the stricter requirements for other energy efficiency measures analyzed in this study.

Overall, adoption of the LEC design in all 50 states leads to average nationwide percentage reductions in energy use, energy costs, and carbon emissions greater than those realized by *ASHRAE 90.1-2007*. The average reduction in energy use is 17.8 % over current state energy codes while energy costs and carbon emissions realize average reductions of 22.6 % and 20.4 %, respectively. The reductions in energy use and carbon emissions are cost-effective, with life-cycle costs decreasing by 1.1 % on average for a 10-year study period.

States with current energy codes based on older editions of *ASHRAE 90.1* realize greater percentage reductions in energy use, energy costs, and carbon emissions for the *ASHRAE 90.1-2007* design. For a small office building, the 13 states with reductions in energy use of at least 10 % have no state energy code or have adopted *ASHRAE 90.1-2001*. For the LEC design, 14 of the 18 states that realize reductions in energy use greater than 25 % have no state energy code or have adopted *ASHRAE 90.1-1999/2001*, including all 13 states with reductions greater than 30 %. Similar trends hold for energy costs and energy-related carbon emissions.

Over all building types, states located in the warmest climates realize the greatest reductions in energy use from adopting the "Low Energy Case" (LEC) design because several of the energy efficiency improvements (e.g., overhangs and daylighting controls) are more beneficial for warmer climates. However, states in colder climates see greater percentage reductions in energy costs and carbon emissions per percentage reduction in energy use because the energy efficiency measures tend to shift some energy use from electricity to natural gas consumption. Electricity is more expensive per unit of energy and typically has greater CO_2e emissions per unit of energy relative to natural gas. Therefore the shift of energy consumption from electricity to natural gas can lead to greater reductions in energy costs and energy-related carbon emissions than reductions in total energy use. In an extreme case, cities located in Zone 8 realize a reduction in energy costs and carbon emissions while realizing an increase in total energy use.

The results for the *ASHRAE 90.1-2007* design have some similarities and some differences relative to the results for the LEC design. Similar to the LEC design, the current state energy codes are a key driver of variation in the results. The variation across climate zones diverges depending on the state energy code. For locations in states that have not adopted any state energy code or have adopted older editions of *ASHRAE 90.1* (*-2001*), warmer climate zones realize greater percentage reductions in energy use. For cities located in states that have adopted *ASHRAE 90.1-2004*, the percentage reductions in energy use do not follow the same trend. Instead the percentage changes are the greatest for cities in Zone 2 followed by Zone 7 and smallest for cities in Zone 1 and Zone 3.

Similar to the LEC design results, some cities realize a shift in energy use from electricity to natural gas, which decreases energy costs and carbon emissions by a greater percentage than the percentage decrease in energy consumption. However, when averaged across all cities in a climate zone, nearly all zones realize smaller percentage reductions in carbon emissions than the percentage reductions in energy use because adopting *ASHRAE 90.1-2007* decreases consumption of natural gas by a greater percentage than electricity for most cities.

The length of the study period impacts life-cycle cost-effectiveness to some degree. Assuming nationwide adoption of the LEC design, average life-cycle costs decrease by 1.1 %, on average, for all building types and locations over a 10-year study period. The percentage decrease in life-cycle costs is 1.4 % for a 20-year, 1.8 % for a 30-year, and 1.9 % for a 40-year study period. As the study period length increases from 5 years to 40 years, life-cycle cost-effectiveness tends to increase for more energy efficient commercial building designs.

9.1.2 Total Changes

By combining the amount of new floor area in a state with its average impacts in a state for each building type, it is possible to estimate the magnitude of the impacts that nationwide adoption of a given building design would have at the state and national levels. States with the most newly constructed commercial building floor area tend to realize the greatest total energy use, energy cost, energy-related carbon emissions, and life-cycle cost reductions from adopting the *ASHRAE 90.1-2007* and LEC designs even if those states do not realize the greatest percentage reductions. California, Florida, and Texas realize the greatest reductions in energy use (>1900 GWh) from adopting the LEC design. In comparison, states with the smallest amount of new floor area (Alaska, Delaware, Montana, Rhode Island, Vermont, and Wyoming) realize savings of less than 100 GWh from adopting the LEC design. For the nineteen states that have not yet adopted the *ASHRAE 90.1-2007* design, Arizona realizes the greatest reductions in energy use (946 GWh) from doing so, while states with the smallest amount of new floor area (Alaska, Wyoming, Hawaii, Maine, North Dakota, South Dakota, and Wyoming) realize savings of less than 106 GWh. Similar trends occur for total energy cost reductions and energy-related carbon emissions savings.

The nationwide adoption of more efficient energy codes decreases total life-cycle costs. Adopting the LEC design decreases total life-cycle costs for 48 of 50 states for a 10-year study period, with Florida ($151.3 million), California ($124.9 million), and Texas ($106.8 million) realizing the greatest life-cycle cost savings. The two states that realize an increase in life-cycle costs are Oregon ($0.4 million) and Washington ($11.5 million). For a 10-year study period, adopting the *ASHRAE 90.1-2007* design reduces total life-cycle costs for 17 of 19 states, including 8 of 10 that have adopted an older edition of *ASHRAE 90.1* or have not yet adopted a state energy code for commercial buildings. The greatest life-cycle cost savings are realized by Colorado ($53.9 million), Arizona ($30.8 million), and Alabama ($25.7 million). The two states that realize an increase in total life-cycle costs are Kansas ($2.9 million) and Oklahoma ($5.7 million).

The state-level impacts are aggregated to determine the total impact of nationwide adoption of both the *ASHRAE 90.1-2007* and LEC designs. Nationwide adoption of the LEC design leads to reductions totaling 34.4 TWh in energy consumption, $2.8 billion in energy costs, 26.3 million metric tons in energy-related carbon emissions, and $1.0 billion in life-cycle costs for a 10-year study period. Nationwide adoption of the *ASHRAE 90.1-2007* design leads to reductions totaling 4.9 TWh in energy consumption, $312 million in energy costs, 3.8 million metric tons in energy-related carbon emissions, and $173 million in life-cycle costs for a 10-year study period. An increase in the study period length increases the total savings for all four impacts because as the length of the study period increases, energy cost savings become a greater fraction of total life-cycle cost savings.

9.1.3 Change per Unit of Floor Area

The total savings estimates are driven primarily by the average annual amount of new floor area in a state. After controlling for the amount of new floor area, the relative savings in energy use, energy costs, carbon emissions, and life-cycle costs per unit of floor area across states is similar to the average percentage changes in each impact. States that have adopted older editions of *ASHRAE 90.1* or have no energy code realize greater per unit savings in energy use, energy costs, and carbon emissions from adopting the LEC design. However, since these per unit changes account for the amount of new floor area for each building type, the results more precisely estimate the impacts. States that have adopted the *ASHRAE 90.1-2001* design realize the greatest life-cycle cost savings per unit of floor area from adopting both the *ASHRAE 90.1-2007* and LEC designs. On the other hand, states that have no state energy code realize varying levels of savings from adopting both the *ASHRAE 90.1-2007* and LEC designs.

In general, the states that realize the greatest reductions in energy use per unit of floor area also realize the greatest reductions in energy costs and energy-related carbon emissions per unit of floor area. However, states with higher average electricity prices and electricity emissions rates, and states that realize a greater shift of fuel consumption from electricity to natural gas, realize greater reductions in energy costs and carbon emissions holding energy use savings constant.

The changes per unit of floor area vary across Census regions, with the same trends holding for adoption of the *ASHRAE 90.1-2007* and LEC designs. The South realizes the greatest energy use savings per unit of floor area because all states in the region are located in warmer climate zones. The West realizes the greatest life-cycle cost savings per unit of floor area, which is a result of a number of factors, including the baseline energy codes for the cities located in the Census region, the regional average electricity price, average energy use savings, and local construction costs. Similar to state-level results, energy costs and carbon emissions savings vary from energy use savings per unit of floor area. The Northeast realizes the greatest energy cost savings per unit energy use savings due to its higher average electricity price. The Midwest realizes the greatest carbon emissions savings per unit of energy use savings because its average electricity emissions rate is much higher than in the other Census regions.

9.1.4 Incremental Changes from Adopting More Stringent Standard Editions

The incremental impacts in a state from adopting each newer edition of *ASHRAE 90.1* lead to some interesting conclusions. For the nine states that have no state energy code, adoption of *ASHRAE 90.1-2001* would lead to minimal energy use reductions (16 kWh/m^2) while significantly increasing total life-cycle costs (\$15.39/m^2).[27] The reason for this result is that the primary changes in the standard from *ASHRAE 90.1-1999* to *ASHRAE 90.1-2001* target the required efficiencies of HVAC equipment. The additional first costs of increasing the efficiency of HVAC equipment appear to be greater than the energy cost savings realized over the 10-year study period.

The adoption of *ASHRAE 90.1-2004* leads to significant average reductions in energy use (112 kWh/m^2) while significantly decreasing total life-cycle costs (\$15.52/m^2), and entirely offsets the increase in life-cycle costs for five of the nine states with no state code. One state, Alaska, realizes an increase in energy use relative to *ASHRAE 90.1-2001*, which is a result of building requirements being relaxed for some cities due to the climate zone consolidation from *ASHRAE 90.1-2001* to *ASHRAE 90.1-2004*.

The adoption of *ASHRAE 90.1-2007* leads to significantly smaller average incremental reductions in energy use (71 kWh/m^2) and life-cycle costs (\$3.04/m^2) relative to adopting *ASHRAE 90.1-2004*. Two of the nineteen states (Arkansas and Oklahoma) realize an increase in life-cycle costs relative to *ASHRAE 90.1-2004*.

The adoption of the LEC design leads to the greatest incremental impacts on total energy use (202 kWh/m^2), and similar incremental impacts on life-cycle costs (\$4.24/m^2) as *ASHRAE 90.1-2007* for the nineteen states that have not yet adopted *ASHRAE 90.1-2007*. Only one of the nineteen states (West Virginia) realizes an increase in life-cycle costs relative to *ASHRAE 90.1-2007*.

9.2 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

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[27] Excludes Arizona because three of the six cities in the BIRDS database have adopted *ASHRAE 90.1-2004* as their local energy code.

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 database should be expanded to include alternative fuel source options, such as heating oil use in the New England area.

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 % glazed. For this reason, the results should be considered as general magnitudes instead of hard numbers. Future research should include additional prototypes, such as the DOE Benchmark Buildings, in the database. 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 BIRDS could be improved.

The analysis in this study ignores the impacts that 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 HVAC 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. Future research should consider the impact the assumed plug and process loads 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 applies 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 11 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, MRR, 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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A Building Type, New Construction, and Emissions Rates

Table A-1 CBECS Categories and Subcategories

Category	Subcategory
Education	elementary or middle school
	high school
	college or university
	preschool or daycare
	adult education
	career or vocational training
	religious education
Food Sales	grocery store or food market
	gas station with a convenience store;
	convenience store
Food Service	fast food
	restaurant or cafeteria
Health Care Inpatient	hospital
	inpatient rehabilitation
Health Care Outpatient	medical office (see previous column)
	clinic or other outpatient health care
	outpatient rehabilitation
	veterinarian
Lodging	motel or inn
	hotel
	dormitory, fraternity, or sorority
	retirement home
	nursing home, assisted living, etc.
	convent or monastery
	shelter, orphanage, halfway house

Category	Subcategory
Public Assembly	social or meeting
	recreation
	entertainment or culture
	library
	funeral home
	student activities center
	armory
	exhibition hall
	broadcasting studio
	transportation terminal
Public Order and Safety	police station
	fire station
	jail, reformatory, or penitentiary
	courthouse or probation office
Religious Worship	None
Service	vehicle service or vehicle repair shop
	vehicle storage/ maintenance (car barn)
	repair shop
	dry cleaner or laundromat
	post office or postal center
	car wash
	gas station
	photo processing shop
	beauty parlor or barber shop
	tanning salon
	copy center or printing shop
	kennel

Mercantile Non-Mall	retail store beer, wine, or liquor store rental center dealership or showroom for vehicles or boats studio/gallery
Mercantile Malls	enclosed mall strip shopping center
Office	administrative or professional office government office mixed-use office bank or other financial institution medical office (see previous column) sales office contractor's office non-profit or social services research and development city hall or city center religious office call center

Warehouse and Storage	refrigerated warehouse non-refrigerated warehouse distribution or shipping center
Other	airplane hangar crematorium laboratory telephone switching agricultural with some retail space manufacturing or industrial with some retail space data center or server farm
Vacant	None

Table A-2 New Commercial Building Construction Volume for 2003 through 2007 by State and Building Type (S-I)

State	Building Construction Volume (1,000 m²)									
	Apartment	Healthcare	Hotel	Office	Public Assembly	Restaurant	Retail	School	Warehouse	No Prototype	Total
AK	19	130	126	226	111	13	208	231	126	259	1448
AL	801	705	853	1504	639	169	2485	1534	842	1740	11 272
AR	118	465	483	647	335	77	1359	1295	335	815	5928
AZ	1043	1505	1047	4030	1180	271	4891	2294	3721	3808	23 790
CA	9761	3310	3129	9219	3092	534	10 623	7085	13 364	12 345	72 462
CO	2033	1387	997	2158	708	199	2896	1654	1541	2889	16 461
CT	611	403	489	618	510	65	1245	1194	817	1271	7223
DC	1174	71	111	1462	112	4	104	191	34	830	4092
DE	70	155	124	224	119	16	237	290	160	323	1719
FL	21 397	3399	2979	9031	3124	678	11 904	7760	9692	12 748	82 712
GA	3696	1551	1510	3630	1212	331	5893	5580	7449	5350	36 202
HI	1280	91	92	171	59	9	273	92	132	485	2682
IA	143	639	427	999	657	74	1350	1262	621	1062	7234
ID	233	372	221	716	230	46	699	636	360	496	4008
IL	7303	1765	1304	2930	1714	232	5660	3083	6473	4179	34 643
IN	360	1728	856	1746	1323	255	3302	2558	3771	2415	18 313
KS	98	533	353	877	295	97	1122	826	513	670	5384
KY	268	757	643	1167	760	138	1667	1270	2001	1106	9778
LA	169	650	807	1175	593	135	1736	842	1011	1379	8498
MA	2959	728	884	1103	632	121	1772	1356	854	2484	12895
MD	3341	813	826	2802	580	109	1549	1527	1989	3388	16 924
ME	64	209	166	224	134	34	566	313	281	494	2485
MI	446	1797	713	1696	1359	200	3245	2058	864	2442	14 820
MN	1437	1018	473	1633	527	102	2135	1175	803	2342	11 645
MO	875	940	881	1226	780	158	2513	1626	819	1972	11 791
MS	150	336	479	631	411	55	1166	743	1593	692	6255
MT	45	122	118	149	94	18	253	174	76	142	1190
NC	1607	1362	1178	3368	1119	230	4472	3418	1910	3520	22 185
ND	7	118	91	138	113	14	331	174	57	100	1145
NE	147	453	303	631	331	54	1149	514	340	676	4599
NH	141	227	226	276	154	51	648	411	191	438	2763
NJ	2807	796	943	1235	774	112	2494	2627	3008	2587	17 382
NM	89	247	418	617	350	62	765	752	292	491	4083
NV	2867	528	2963	1626	1195	157	2382	960	1669	3231	17 579
NY	11 622	1639	1959	3330	1075	210	3633	2247	1286	3354	30 354
OH	635	2452	925	2674	1266	372	5132	4452	3382	3243	24 533
OK	115	794	512	763	878	141	1364	1179	932	1271	7950
OR	1253	918	360	922	383	68	1382	651	1142	1648	8727
PA	1503	1908	1406	2424	1354	219	3762	3660	3512	3556	23 305
RI	238	60	192	251	81	26	278	197	114	236	1674
SC	1981	746	563	1539	539	168	2600	2222	1101	2132	13 590
SD	13	119	86	257	126	13	341	268	88	205	1515
TN	987	1036	683	2296	733	199	3581	1809	2698	2337	16 360
TX	5548	4508	3571	8328	3325	849	13 121	12 693	10 609	9676	72 230
UT	622	569	314	1365	475	76	1424	1269	1274	1201	8590
VA	3502	1011	1361	3693	1096	200	3014	2387	1826	4406	22 495
VT	161	99	96	113	71	6	63	136	88	165	998
WA	3397	1085	871	2435	833	107	2504	1841	1880	3598	18 551
WI	906	1519	583	1556	746	137	2489	1129	882	1981	11 928
WV	65	215	148	193	117	39	668	484	179	288	2397
WY	4	72	166	66	127	9	158	254	67	228	1151
Total	100 111	48 059	41 007	92 089	38 550	7661	128 609	94 383	98 773	118 693	767 935

Table A-3 New Commercial Building Construction Volume for 2003 through 2007 by State and Building Type (I-P)

State	Building Construction Volume (1,000 ft^2)										
	Apartment	Healthcare	Hotel	Office	Public Assembly	Restaurant	Retail	School	Warehouse	No Prototype	Total
AK	201	1401	1357	2428	1190	137	2240	2484	1356	2787	15 581
AL	8619	7587	9184	16 191	6876	1821	26 748	16 514	9060	18 729	121 329
AR	1272	5000	5198	6962	3611	829	14 624	13 936	3609	8768	63 810
AZ	11 223	16 195	11 272	43 383	12 701	2918	52 646	24 692	40 052	40 986	256 068
CA	105 071	35 633	33 678	99 228	33 281	5747	114 344	76 262	143 853	132 882	779 978
CO	21 885	14 926	10 735	23 225	7618	2142	31 177	17 804	16 582	31 094	177 186
CT	6582	4333	5261	6651	5485	698	13 403	12 856	8798	13 679	77 746
DC	12 636	769	1199	15 734	1202	38	1122	2051	363	8934	44 047
DE	755	1672	1330	2410	1282	173	2551	3126	1722	3480	18 501
FL	230 315	36 591	32 071	97 212	33 622	7299	128 133	83 524	104 327	137 213	890 306
GA	39 780	16 699	16 254	39 076	13 043	3563	63 430	60 062	80 180	57 586	389 672
HI	13 773	979	989	1838	630	95	2939	985	1417	5220	28 865
IA	1542	6875	4598	10 749	7069	796	14 534	13 586	6688	11 426	77 863
ID	2506	4001	2375	7703	2478	493	7526	6847	3876	5343	43 147
IL	78 609	18 998	14 037	31 542	18 451	2497	60 928	33 180	69 674	44 977	372 893
IN	3875	18 600	9210	18 791	14 242	2747	35 539	27 535	40 591	25 992	197 123
KS	1057	5734	3795	9442	3178	1039	12 076	8892	5521	7216	57 950
KY	2888	8150	6922	12 558	8185	1489	17 941	13 672	21 538	11 906	105 248
LA	1823	7001	8689	12 647	6386	1454	18 681	9061	10 886	14 841	91 469
MA	31 854	7832	9516	11 868	6808	1306	19 079	14 599	9197	26 742	138 802
MD	35 967	8750	8888	30 163	6242	1173	16 672	16 432	21 414	36 463	182 163
ME	687	2245	1791	2411	1441	368	6088	3374	3021	5320	26 745
MI	4800	19 346	7671	18 251	14 629	2153	34 934	22 151	9305	26 283	159 523
MN	15 465	10 954	5093	17 575	5673	1098	22 985	12 643	8643	25 212	125 342
MO	9420	10 121	9483	13 197	8395	1705	27 054	17 497	8818	21 226	126 915
MS	1613	3618	5153	6789	4423	587	12 551	7999	17 146	7447	67 326
MT	481	1313	1265	1602	1007	195	2723	1871	821	1533	12 810
NC	17 294	14 663	12 678	36 249	12 044	2481	48 139	36 794	20 559	37 891	238 792
ND	76	1265	982	1490	1221	155	3567	1871	617	1077	12 320
NE	1586	4880	3263	6790	3562	577	12 369	5533	3660	7279	49 498
NH	1523	2440	2437	2974	1653	548	6970	4421	2059	4717	29 741
NJ	30 209	8563	10 145	13 295	8335	1210	26 842	28 280	32 383	27 841	187 103
NM	957	2655	4499	6636	3770	670	8235	8097	3142	5290	43 950
NV	30 856	5684	31 894	17 504	12 863	1691	25 644	10 337	17 969	34 776	189 218
NY	125 095	17 639	21 083	35 842	11 572	2259	39 107	24 186	13 845	36 104	326 732
OH	6832	26 393	9959	28 780	13 630	4004	55 245	47 919	36 400	34 909	264 071
OK	1242	8547	5511	8216	9450	1523	14 686	12 691	10 032	13 680	85 577
OR	13 492	9885	3878	9927	4118	728	14 881	7004	12 291	17 738	93 941
PA	16 177	20 535	15 135	26 096	14 577	2361	40 489	39 397	37 805	38 280	250 852
RI	2559	649	2069	2707	877	278	2990	2125	1228	2540	18 021
SC	21 321	8033	6056	16 562	5801	1810	27 984	23 920	11 848	22 949	146 284
SD	142	1285	922	2767	1354	138	3668	2884	950	2202	16 312
TN	10 621	11 152	7347	24 718	7891	2145	38 548	19 476	29 045	25 152	176 095
TX	59 723	48 519	38 437	89 641	35 794	9142	141 238	136 629	114 193	104 156	777 473
UT	6695	6123	3384	14 698	5110	822	15 331	13 657	13 716	12 926	92 462
VA	37 694	10 887	14 646	39 749	11 794	2149	32 438	25 691	19 659	47 422	242 129
VT	1736	1063	1030	1214	765	68	674	1463	946	1777	10 737
WA	36 566	11 683	9378	26 209	8964	1147	26 954	19 817	20 236	38 731	199 685
WI	9754	16 350	6273	16 751	8030	1474	26 793	12 148	9497	21 325	128 395
WV	697	2314	1592	2081	1259	421	7191	5215	1930	3098	25 797
WY	42	774	1787	713	1370	97	1696	2737	718	2453	12 387
Total	1 077 585	517 302	441 399	991 233	414 953	82 459	1 384 339	1 015 925	1 063 186	1 277 597	8 265 977

Table A-4 New Commercial Building Construction Share by State and Building Type

State	Percentage of Building Construction Volume										
	Apartment	Healthcare	Hotel	Office	Public Assembly	Restaurant	Retail	School	Warehouse	No Prototype	Total	Rep. by Study
AK	1.3 %	9.0 %	8.7 %	15.6 %	7.6 %	0.9 %	14.4 %	15.9 %	8.7 %	17.9 %	100.0 %	56.8 %
AL	7.1 %	6.3 %	7.6 %	13.3 %	5.7 %	1.5 %	22.0 %	13.6 %	7.5 %	15.4 %	100.0 %	65.2 %
AR	2.0 %	7.8 %	8.1 %	10.9 %	5.7 %	1.3 %	22.9 %	21.8 %	5.7 %	13.7 %	100.0 %	67.1 %
AZ	4.4 %	6.3 %	4.4 %	16.9 %	5.0 %	1.1 %	20.6 %	9.6 %	15.6 %	16.0 %	100.0 %	57.1 %
CA	13.5 %	4.6 %	4.3 %	12.7 %	4.3 %	0.7 %	14.7 %	9.8 %	18.4 %	17.0 %	100.0 %	55.7 %
CO	12.4 %	8.4 %	6.1 %	13.1 %	4.3 %	1.2 %	17.6 %	10.0 %	9.4 %	17.5 %	100.0 %	60.4 %
CT	8.5 %	5.6 %	6.8 %	8.6 %	7.1 %	0.9 %	17.2 %	16.5 %	11.3 %	17.6 %	100.0 %	58.5 %
DC	28.7 %	1.7 %	2.7 %	35.7 %	2.7 %	0.1 %	2.5 %	4.7 %	0.8 %	20.3 %	100.0 %	74.4 %
DE	4.1 %	9.0 %	7.2 %	13.0 %	6.9 %	0.9 %	13.8 %	16.9 %	9.3 %	18.8 %	100.0 %	55.9 %
FL	25.9 %	4.1 %	3.6 %	10.9 %	3.8 %	0.8 %	14.4 %	9.4 %	11.7 %	15.4 %	100.0 %	65.0 %
GA	10.2 %	4.3 %	4.2 %	10.0 %	3.3 %	0.9 %	16.3 %	15.4 %	20.6 %	14.8 %	100.0 %	57.0 %
HI	47.7 %	3.4 %	3.4 %	6.4 %	2.2 %	0.3 %	10.2 %	3.4 %	4.9 %	18.1 %	100.0 %	71.4 %
IA	2.0 %	8.8 %	5.9 %	13.8 %	9.1 %	1.0 %	18.7 %	17.4 %	8.6 %	14.7 %	100.0 %	58.8 %
ID	5.8 %	9.3 %	5.5 %	17.9 %	5.7 %	1.1 %	17.4 %	15.9 %	9.0 %	12.4 %	100.0 %	63.6 %
IL	21.1 %	5.1 %	3.8 %	8.5 %	4.9 %	0.7 %	16.3 %	8.9 %	18.7 %	12.1 %	100.0 %	59.2 %
IN	2.0 %	9.4 %	4.7 %	9.5 %	7.2 %	1.4 %	18.0 %	14.0 %	20.6 %	13.2 %	100.0 %	49.6 %
KS	1.8 %	9.9 %	6.5 %	16.3 %	5.5 %	1.8 %	20.8 %	15.3 %	9.5 %	12.5 %	100.0 %	62.6 %
KY	2.7 %	7.7 %	6.6 %	11.9 %	7.8 %	1.4 %	17.0 %	13.0 %	20.5 %	11.3 %	100.0 %	52.7 %
LA	2.0 %	7.7 %	9.5 %	13.8 %	7.0 %	1.6 %	20.4 %	9.9 %	11.9 %	16.2 %	100.0 %	57.2 %
MA	22.9 %	5.6 %	6.9 %	8.6 %	4.9 %	0.9 %	13.7 %	10.5 %	6.6 %	19.3 %	100.0 %	63.6 %
MD	19.7 %	4.8 %	4.9 %	16.6 %	3.4 %	0.6 %	9.2 %	9.0 %	11.8 %	20.0 %	100.0 %	60.0 %
ME	2.6 %	8.4 %	6.7 %	9.0 %	5.4 %	1.4 %	22.8 %	12.6 %	11.3 %	19.9 %	100.0 %	55.0 %
MI	3.0 %	12.1 %	4.8 %	11.4 %	9.2 %	1.3 %	21.9 %	13.9 %	5.8 %	16.5 %	100.0 %	56.4 %
MN	12.3 %	8.7 %	4.1 %	14.0 %	4.5 %	0.9 %	18.3 %	10.1 %	6.9 %	20.1 %	100.0 %	59.7 %
MO	7.4 %	8.0 %	7.5 %	10.4 %	6.6 %	1.3 %	21.3 %	13.8 %	6.9 %	16.7 %	100.0 %	61.7 %
MS	2.4 %	5.4 %	7.7 %	10.1 %	6.6 %	0.9 %	18.6 %	11.9 %	25.5 %	11.1 %	100.0 %	51.5 %
MT	3.8 %	10.2 %	9.9 %	12.5 %	7.9 %	1.5 %	21.3 %	14.6 %	6.4 %	12.0 %	100.0 %	63.5 %
NC	7.2 %	6.1 %	5.3 %	15.2 %	5.0 %	1.0 %	20.2 %	15.4 %	8.6 %	15.9 %	100.0 %	64.3 %
ND	0.6 %	10.3 %	8.0 %	12.1 %	9.9 %	1.3 %	29.0 %	15.2 %	5.0 %	8.7 %	100.0 %	66.1 %
NE	3.2 %	9.9 %	6.6 %	13.7 %	7.2 %	1.2 %	25.0 %	11.2 %	7.4 %	14.7 %	100.0 %	60.8 %
NH	5.1 %	8.2 %	8.2 %	10.0 %	5.6 %	1.8 %	23.4 %	14.9 %	6.9 %	15.9 %	100.0 %	63.5 %
NJ	16.1 %	4.6 %	5.4 %	7.1 %	4.5 %	0.6 %	14.3 %	15.1 %	17.3 %	14.9 %	100.0 %	58.8 %
NM	2.2 %	6.0 %	10.2 %	15.1 %	8.6 %	1.5 %	18.7 %	18.4 %	7.1 %	12.0 %	100.0 %	66.2 %
NV	16.3 %	3.0 %	16.9 %	9.3 %	6.8 %	0.9 %	13.6 %	5.5 %	9.5 %	18.4 %	100.0 %	62.3 %
NY	38.3 %	5.4 %	6.5 %	11.0 %	3.5 %	0.7 %	12.0 %	7.4 %	4.2 %	11.1 %	100.0 %	75.8 %
OH	2.6 %	10.0 %	3.8 %	10.9 %	5.2 %	1.5 %	20.9 %	18.1 %	13.8 %	13.2 %	100.0 %	57.8 %
OK	1.5 %	10.0 %	6.4 %	9.6 %	11.0 %	1.8 %	17.2 %	14.8 %	11.7 %	16.0 %	100.0 %	51.3 %
OR	14.4 %	10.5 %	4.1 %	10.6 %	4.4 %	0.8 %	15.8 %	7.5 %	13.1 %	18.9 %	100.0 %	53.1 %
PA	6.4 %	8.2 %	6.0 %	10.4 %	5.8 %	0.9 %	16.1 %	15.7 %	15.1 %	15.3 %	100.0 %	55.7 %
RI	14.2 %	3.6 %	11.5 %	15.0 %	4.9 %	1.5 %	16.6 %	11.8 %	6.8 %	14.1 %	100.0 %	70.6 %
SC	14.6 %	5.5 %	4.1 %	11.3 %	4.0 %	1.2 %	19.1 %	16.4 %	8.1 %	15.7 %	100.0 %	66.8 %
SD	0.9 %	7.9 %	5.7 %	17.0 %	8.3 %	0.8 %	22.5 %	17.7 %	5.8 %	13.5 %	100.0 %	64.5 %
TN	6.0 %	6.3 %	4.2 %	14.0 %	4.5 %	1.2 %	21.9 %	11.1 %	16.5 %	14.3 %	100.0 %	58.4 %
TX	7.7 %	6.2 %	4.9 %	11.5 %	4.6 %	1.2 %	18.2 %	17.6 %	14.7 %	13.4 %	100.0 %	61.1 %
UT	7.2 %	6.6 %	3.7 %	15.9 %	5.5 %	0.9 %	16.6 %	14.8 %	14.8 %	14.0 %	100.0 %	59.0 %
VA	15.6 %	4.5 %	6.0 %	16.4 %	4.9 %	0.9 %	13.4 %	10.6 %	8.1 %	19.6 %	100.0 %	62.9 %
VT	16.2 %	9.9 %	9.6 %	11.3 %	7.1 %	0.6 %	6.3 %	13.6 %	8.8 %	16.6 %	100.0 %	57.6 %
WA	18.3 %	5.9 %	4.7 %	13.1 %	4.5 %	0.6 %	13.5 %	9.9 %	10.1 %	19.4 %	100.0 %	60.1 %
WI	7.6 %	12.7 %	4.9 %	13.0 %	6.3 %	1.1 %	20.9 %	9.5 %	7.4 %	16.6 %	100.0 %	57.0 %
WV	2.7 %	9.0 %	6.2 %	8.1 %	4.9 %	1.6 %	27.9 %	20.2 %	7.5 %	12.0 %	100.0 %	66.7 %
WY	0.3 %	6.2 %	14.4 %	5.8 %	11.1 %	0.8 %	13.7 %	22.1 %	5.8 %	19.8 %	100.0 %	57.1 %
Total	13.0 %	6.3 %	5.3 %	12.0 %	5.0 %	1.0 %	16.7 %	12.3 %	12.9 %	15.5 %	100.0 %	60.4 %

Table A-5 CO_2, CH_4, and N_2O Emissions Rates Electricity Generation by State

State	CO_2 (t/GWh)	CH4 (t/GWh)	N2O (t/GWh)	State	CO_2 (t/GWh)	CH4 (t/GWh)	N2O (t/GWh)
AK	603.4	57.9	1.9	MT	542.8	30.1	0.4
AL	804.2	42.7	0.5	NC	616.6	30.5	0.2
AR	695.9	58.6	1.7	ND	851.1	40.4	0.2
AZ	746.9	53.2	1.2	NE	851.1	40.4	0.2
CA	450.0	45.8	1.5	NH	550.4	47.0	1.4
CO	938.8	54.0	0.8	NJ	618.7	33.4	0.4
CT	550.4	47.0	1.4	NM	778.5	55.3	1.3
DE	618.7	33.4	0.4	NV	465.6	27.6	0.4
FL	767.5	57.2	1.5	NY	480.7	32.3	0.8
GA	804.2	42.7	0.5	OH	835.7	38.9	0.2
HI	807.1	28.0	0.1	OK	904.8	63.9	1.4
IA	851.1	40.4	0.2	OR	465.6	27.6	0.4
ID	465.6	27.6	0.4	PA	672.9	34.7	0.4
IL	948.3	44.4	0.2	RI	550.4	47.0	1.4
IN	835.7	38.9	0.2	SC	616.6	30.5	0.2
KS	926.0	44.8	0.3	SD	851.1	40.4	0.2
KY	781.9	36.9	0.2	TN	781.9	36.9	0.2
LA	719.2	59.2	1.6	TX	790.9	65.8	1.8
MA	550.4	47.0	1.4	UT	465.6	27.6	0.4
MD	618.7	33.4	0.4	VA	689.6	33.3	0.2
ME	550.4	47.0	1.4	VT	550.4	47.0	1.4
MI	861.4	46.8	0.6	WA	465.6	27.6	0.4
MN	851.1	40.4	0.2	WI	860.7	44.1	0.4
MO	939.4	44.6	0.2	WV	835.7	38.9	0.2
MS	709.8	48.3	1.0	WY	623.7	36.4	0.5

B Percentage Changes by Building Type for the Nationwide Adoption of the LEC Design

Table B-1 4-Story Apartment Building Summary Table for LEC and 10-Year Study Period

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
AK	-12.7	-31.2	-25.0	-1.7
AL	-35.2	-40.3	-42.9	-3.4
AR	-29.0	-36.6	-39.4	-1.8
AZ	-26.6	-31.1	-32.4	-1.6
CA	-16.1	-22.5	-19.8	0.2
CO	-21.9	-36.2	-37.9	-1.2
CT	-9.5	-18.5	-15.1	-0.1
DE	-10.4	-15.0	-16.0	-0.2
FL	-16.6	-17.7	-17.8	-0.3
GA	-14.3	-17.7	-18.8	0.4
HI	-20.4	-20.4	-20.4	-1.7
IA	-9.8	-15.8	-16.8	0.5
ID	-10.2	-14.8	-14.9	0.8
IL	-9.4	-17.1	-17.1	0.3
IN	-10.1	-16.0	-17.1	0.6
KS	-24.9	-35.3	-39.1	-1.6
KY	-11.5	-15.6	-17.9	0.7
LA	-15.4	-17.6	-18.3	0.5
MA	-9.1	-16.8	-14.8	0.1
MD	-10.9	-17.1	-16.4	0.2
ME	-19.9	-32.9	-31.9	-2.6
MI	-8.5	-15.2	-16.3	0.4
MN	-13.8	-18.0	-18.6	0.2
MO	-25.4	-33.3	-38.6	-1.0
MS	-35.7	-42.4	-42.6	-3.3

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
MT	-9.6	-15.2	-14.5	0.6
NC	-13.5	-17.0	-18.1	0.4
ND	-17.5	-30.8	-33.4	-1.0
NE	-9.8	-16.3	-17.2	0.7
NH	-9.5	-15.8	-14.7	-0.3
NJ	-10.3	-17.8	-16.0	0.4
NM	-13.6	-20.0	-20.0	0.5
NV	-14.5	-20.7	-18.8	-0.1
NY	-9.2	-17.5	-13.8	0.0
OH	-9.6	-16.0	-17.1	0.5
OK	-27.2	-35.1	-40.8	-1.3
OR	-10.0	-15.0	-15.4	1.1
PA	-9.5	-14.9	-16.0	0.6
RI	-9.2	-15.5	-15.1	0.2
SC	-18.0	-22.6	-23.2	-0.1
SD	-21.2	-34.1	-35.9	-1.7
TN	-16.1	-20.5	-21.3	-0.1
TX	-15.0	-18.6	-18.6	0.0
UT	-10.7	-17.6	-15.7	0.7
VA	-12.6	-17.0	-18.1	0.5
VT	-9.5	-15.5	-14.6	-0.2
WA	-8.8	-12.8	-14.0	1.2
WI	-9.5	-15.9	-16.4	0.4
WV	-25.3	-29.8	-38.9	-0.8
WY	-22.7	-36.6	-36.4	-1.4
Avg.	**-14.8**	**-21.2**	**-21.6**	**-0.1**

Table B-2 6-Story Apartment Building Summary Table for LEC and 10-Year Study Period

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
AK	-12.2	-31.1	-24.8	-1.5
AL	-35.6	-41.2	-44.1	-3.5
AR	-29.8	-37.9	-40.8	-1.9
AZ	-27.1	-32.5	-34.0	-1.7
CA	-18.2	-26.1	-22.8	-0.1
CO	-22.5	-37.7	-39.5	-1.2
CT	-10.6	-21.8	-17.7	-0.4
DE	-11.2	-17.0	-18.2	-0.4
FL	-17.5	-18.9	-19.0	-0.4
GA	-15.5	-19.5	-20.9	0.3
HI	-20.7	-20.7	-20.7	-1.6
IA	-10.6	-17.6	-18.7	0.5
ID	-11.1	-16.5	-16.5	0.8
IL	-10.5	-20.0	-20.1	0.1
IN	-11.3	-18.7	-20.1	0.5
KS	-25.9	-37.4	-41.4	-1.8
KY	-13.4	-18.6	-21.4	0.5
LA	-16.5	-19.1	-20.0	0.4
MA	-9.8	-19.5	-17.0	0.0
MD	-12.1	-19.9	-19.0	0.0
ME	-19.3	-32.3	-31.4	-2.4
MI	-8.9	-16.7	-17.9	0.3
MN	-13.0	-17.3	-17.9	0.4
MO	-26.5	-35.2	-40.9	-1.1
MS	-36.2	-43.3	-43.5	-3.4

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
MT	-9.5	-15.1	-14.4	0.6
NC	-14.8	-19.2	-20.6	0.2
ND	-17.2	-30.5	-33.1	-0.9
NE	-11.2	-19.5	-20.5	0.6
NH	-9.3	-15.4	-14.4	-0.3
NJ	-11.4	-20.6	-18.5	0.2
NM	-15.1	-23.0	-23.0	0.3
NV	-14.9	-22.9	-20.5	-0.1
NY	-9.6	-19.4	-15.1	-0.1
OH	-10.6	-18.5	-19.9	0.4
OK	-28.1	-36.5	-42.6	-1.5
OR	-10.9	-17.1	-17.7	1.0
PA	-10.4	-17.1	-18.5	0.5
RI	-10.0	-17.9	-17.4	0.0
SC	-18.9	-24.4	-25.1	-0.2
SD	-20.6	-33.5	-35.4	-1.5
TN	-17.3	-22.9	-23.9	-0.3
TX	-16.3	-20.6	-20.6	-0.2
UT	-11.9	-20.5	-18.2	0.6
VA	-14.4	-20.0	-21.3	0.3
VT	-9.2	-15.1	-14.2	-0.1
WA	-9.4	-14.4	-15.8	1.2
WI	-9.3	-15.5	-16.0	0.5
WV	-26.2	-31.2	-41.0	-0.8
WY	-22.5	-36.3	-36.2	-1.3
Avg.	**-9.5**	**-15.1**	**-23.3**	**-0.2**

Table B-3 4-Story Dormitory Summary Table for LEC and 10-Year Study Period

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
AK	-18.1	-34.8	-29.3	-2.4
AL	-36.7	-41.7	-44.2	-2.9
AR	-28.8	-37.1	-40.0	-4.9
AZ	-29.1	-32.1	-32.9	-1.6
CA	-18.2	-22.3	-20.6	-1.3
CO	-24.9	-36.6	-37.9	-4.2
CT	-11.2	-18.9	-16.1	-1.6
DE	-12.3	-16.3	-17.2	-0.5
FL	-17.4	-18.4	-18.5	-2.1
GA	-15.1	-18.1	-19.1	-1.2
HI	-22.1	-22.1	-22.1	-3.6
IA	-11.7	-16.7	-17.5	-0.2
ID	-12.7	-16.4	-16.5	-1.2
IL	-11.1	-17.8	-17.8	-0.3
IN	-11.8	-16.9	-17.9	-0.4
KS	-27.6	-37.1	-40.4	0.3
KY	-12.9	-16.4	-18.3	-1.0
LA	-15.5	-17.8	-18.5	-0.8
MA	-11.1	-17.8	-16.1	-1.3
MD	-12.5	-17.8	-17.2	-0.2
ME	-24.4	-35.6	-34.9	-1.6
MI	-10.7	-16.5	-17.4	-1.2
MN	-19.0	-20.7	-20.9	-1.5
MO	-27.4	-35.0	-39.8	0.2
MS	-39.0	-44.2	-44.4	-1.8

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
MT	-12.9	-17.1	-16.6	-1.2
NC	-14.8	-17.7	-18.5	-0.7
ND	-21.6	-33.7	-36.0	0.3
NE	-11.7	-17.2	-17.9	-0.2
NH	-12.2	-17.0	-16.2	-1.7
NJ	-12.3	-18.6	-17.2	-0.8
NM	-15.3	-19.8	-19.8	-1.6
NV	-17.1	-21.1	-19.9	-1.9
NY	-11.1	-18.2	-15.1	-1.5
OH	-11.2	-16.9	-17.8	-1.2
OK	-27.6	-36.1	-42.2	0.0
OR	-12.7	-16.7	-17.0	-1.0
PA	-11.1	-15.9	-16.8	-0.8
RI	-11.3	-16.7	-16.4	-1.4
SC	-16.9	-21.7	-22.3	-1.3
SD	-24.0	-35.7	-37.3	-1.4
TN	-17.3	-20.4	-20.9	-1.1
TX	-15.5	-18.6	-18.7	-0.9
UT	-12.8	-18.2	-16.8	-1.2
VA	-14.3	-17.9	-18.7	-0.7
VT	-11.9	-16.7	-15.9	-1.6
WA	-11.6	-15.0	-16.0	-0.5
WI	-12.0	-17.0	-17.4	-0.8
WV	-26.7	-31.0	-38.8	-3.3
WY	-26.9	-38.4	-38.3	-0.9
Avg.	**-16.9**	**-22.2**	**-22.6**	**-1.2**

Table B-4 6-Story Dormitory Summary Table for LEC and 10-Year Study Period

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
AK	-11.1	-30.0	-23.7	-2.2
AL	-37.9	-43.7	-46.7	-4.9
AR	-30.8	-39.1	-42.1	-2.9
AZ	-28.3	-33.6	-35.1	-2.4
CA	-17.9	-26.3	-22.7	-0.4
CO	-20.7	-36.0	-37.9	-1.8
CT	-10.4	-21.2	-17.2	-0.7
DE	-11.3	-16.9	-18.0	-0.8
FL	-18.4	-20.0	-20.1	-0.9
GA	-15.5	-19.7	-21.2	-0.1
HI	-23.0	-23.0	-23.0	-2.5
IA	-10.0	-16.4	-17.4	0.2
ID	-10.6	-15.6	-15.7	0.5
IL	-10.3	-19.4	-19.4	-0.2
IN	-11.0	-18.1	-19.4	0.2
KS	-24.8	-36.3	-40.4	-2.6
KY	-12.9	-17.9	-20.6	0.2
LA	-16.7	-19.6	-20.6	0.0
MA	-9.5	-18.7	-16.4	-0.3
MD	-12.0	-19.7	-18.8	-0.4
ME	-18.0	-30.6	-29.7	-3.1
MI	-8.5	-15.9	-17.1	0.1
MN	-11.3	-15.2	-15.7	0.2
MO	-26.0	-34.9	-40.6	-1.9
MS	-38.2	-45.6	-45.9	-4.7
MT	-8.6	-13.6	-12.9	0.3
NC	-14.7	-19.1	-20.4	-0.1
ND	-16.6	-28.8	-31.2	-1.6
NE	-10.9	-18.8	-19.8	0.3
NH	-8.4	-13.8	-12.9	-0.5
NJ	-11.4	-20.4	-18.3	-0.2
NM	-15.2	-22.8	-22.9	-0.1
NV	-14.1	-22.1	-19.6	-0.4
NY	-9.1	-18.3	-14.3	-0.4
OH	-10.3	-17.9	-19.2	0.1
OK	-29.9	-38.5	-44.8	-2.6
OR	-10.6	-16.7	-17.1	0.7
PA	-10.3	-16.8	-18.0	0.2
RI	-9.7	-17.2	-16.7	-0.3
SC	-20.2	-26.0	-26.8	-0.7
SD	-17.3	-30.6	-32.5	-2.0
TN	-16.1	-21.9	-22.9	-0.5
TX	-16.3	-20.9	-20.9	-0.6
UT	-12.0	-20.1	-18.0	0.3
VA	-14.2	-19.6	-20.8	0.0
VT	-8.2	-13.4	-12.6	-0.3
WA	-9.2	-14.1	-15.5	0.9
WI	-8.2	-13.7	-14.2	0.2
WV	-24.4	-29.6	-39.1	-1.4
WY	-19.1	-33.4	-33.2	-1.8
Avg.	**-15.2**	**-22.4**	**-22.8**	**-0.6**

Table B-5 15-Story Hotel Building Summary Table for LEC and 10-Year Study Period

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
AK	-6.9	-23.5	-18.0	-1.8
AL	-30.3	-36.2	-39.2	-3.0
AR	-21.5	-32.1	-36.0	-1.6
AZ	-23.1	-26.4	-27.3	-1.0
CA	-18.2	-24.5	-21.8	0.0
CO	-16.0	-28.8	-30.3	-1.1
CT	-12.7	-21.6	-18.3	-0.5
DE	-13.1	-17.6	-18.5	-0.6
FL	-16.7	-18.8	-19.0	-0.1
GA	-14.5	-18.5	-19.9	0.4
HI	-18.0	-18.1	-18.1	-0.6
IA	-11.0	-15.3	-16.0	0.5
ID	-12.3	-15.9	-15.9	0.7
IL	-11.8	-19.2	-19.2	0.2
IN	-12.3	-18.1	-19.2	0.5
KS	-19.7	-29.4	-32.9	-1.5
KY	-13.7	-17.6	-19.8	0.6
LA	-14.5	-18.1	-19.3	0.6
MA	-11.8	-19.3	-17.4	-0.1
MD	-13.4	-19.4	-18.7	-0.1
ME	-14.0	-23.1	-22.5	-2.3
MI	-10.1	-15.5	-16.4	0.2
MN	-6.8	-6.8	-6.8	0.9
MO	-19.8	-27.5	-32.6	-0.9
MS	-34.4	-37.0	-37.1	-2.8
MT	-9.4	-11.5	-11.3	0.4
NC	-14.9	-18.4	-19.4	0.3
ND	-10.0	-20.8	-22.8	-1.1
NE	-12.7	-18.9	-19.7	0.6
NH	-8.9	-11.2	-10.8	-0.2
NJ	-13.1	-20.2	-18.6	0.1
NM	-15.7	-21.1	-21.1	0.4
NV	-8.8	-14.7	-13.0	0.7
NY	-11.2	-18.0	-15.0	-0.2
OH	-11.8	-18.1	-19.2	0.4
OK	-19.7	-29.9	-37.5	-1.2
OR	-13.8	-18.4	-18.8	0.9
PA	-11.8	-17.1	-18.2	0.4
RI	-12.1	-18.1	-17.7	-0.1
SC	-8.5	-14.6	-15.4	0.9
SD	-11.8	-21.8	-23.2	-1.3
TN	-9.6	-13.6	-14.3	0.8
TX	-14.9	-19.6	-19.6	0.0
UT	-14.2	-20.2	-18.6	0.6
VA	-14.9	-18.8	-19.8	0.4
VT	-9.0	-11.3	-11.0	-0.1
WA	-12.3	-16.2	-17.2	1.1
WI	-8.9	-11.2	-11.4	0.4
WV	-18.9	-23.4	-32.3	-0.6
WY	-13.8	-24.7	-24.6	-1.3
Avg.	**-13.9**	**-19.6**	**-20.0**	**-0.1**

Table B-6 2-Story High School Summary Table for LEC and 10-Year Study Period

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
AK	-7.7	-17.8	-14.0	-1.6
AL	-23.6	-29.4	-32.7	-3.3
AR	-16.5	-25.0	-28.5	-1.8
AZ	-21.5	-27.4	-29.2	-2.8
CA	-13.7	-23.4	-19.2	-1.8
CO	-10.6	-23.1	-25.0	-1.9
CT	-5.3	-17.9	-12.8	-1.9
DE	-6.4	-13.3	-14.8	-1.8
FL	-21.2	-23.4	-23.7	-1.9
GA	-12.6	-18.2	-20.3	-1.6
HI	-26.7	-26.7	-26.7	-4.2
IA	-6.1	-13.8	-15.2	-0.8
ID	-6.0	-11.8	-11.9	-0.2
IL	-5.6	-16.4	-16.5	-1.1
IN	-6.4	-14.8	-16.6	-0.8
KS	-13.7	-23.4	-27.7	-1.5
KY	-8.0	-14.1	-17.8	-0.9
LA	-15.4	-19.5	-21.0	-0.8
MA	-4.6	-15.2	-12.3	-1.1
MD	-7.2	-16.9	-15.6	-1.7
ME	-10.7	-18.9	-18.3	-1.9
MI	-4.6	-12.7	-14.2	-0.8
MN	-9.2	-14.1	-14.9	-1.1
MO	-14.3	-21.7	-27.7	-1.4
MS	-26.7	-33.1	-33.4	-3.4
MT	-9.7	-13.9	-13.3	-0.6
NC	-10.5	-16.2	-18.1	-1.1
ND	-11.1	-18.9	-20.8	-0.9
NE	-5.8	-15.0	-16.4	-0.6
NH	-5.7	-12.3	-11.1	-1.5
NJ	-6.6	-17.8	-15.0	-1.5
NM	-9.6	-19.8	-19.9	-1.0
NV	-9.5	-18.2	-15.4	-1.5
NY	-6.2	-16.7	-11.8	-1.6
OH	-5.6	-14.2	-15.8	-0.8
OK	-15.0	-22.8	-29.7	-1.3
OR	-4.9	-11.5	-12.1	0.0
PA	-5.4	-12.7	-14.3	-0.6
RI	-5.0	-13.7	-13.0	-0.9
SC	-13.8	-19.8	-20.6	-1.3
SD	-10.9	-20.0	-21.7	-1.8
TN	-12.9	-19.9	-21.3	-1.7
TX	-14.7	-21.0	-21.1	-1.7
UT	-5.9	-15.6	-12.8	-0.8
VA	-9.2	-16.4	-18.3	-0.6
VT	-5.9	-12.1	-11.0	-1.4
WA	-4.2	-9.4	-10.9	0.2
WI	-5.9	-12.7	-13.4	-1.1
WV	-13.3	-17.1	-26.4	-1.3
WY	-11.5	-21.2	-21.1	-1.3
Avg.	**-10.6**	**-18.0**	**-18.5**	**-1.3**

Table B-7 8-Story Office Building Summary Table for LEC and 10-Year Study Period

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
AK	-21.3	-25.8	-24.6	0.0
AL	-31.7	-32.2	-32.4	-0.7
AR	-30.0	-31.4	-31.9	-5.2
AZ	-28.1	-28.0	-28.0	-2.3
CA	-21.4	-21.9	-21.8	-2.8
CO	-28.3	-29.7	-29.9	-5.1
CT	-18.3	-21.3	-20.5	-2.7
DE	-19.7	-21.1	-21.3	-3.2
FL	-20.1	-20.2	-20.2	-2.6
GA	-19.5	-20.2	-20.4	-1.7
HI	-21.3	-21.3	-21.3	-3.6
IA	-17.3	-19.6	-19.8	-1.5
ID	-19.3	-20.4	-20.4	-2.4
IL	-17.8	-21.0	-21.0	-2.2
IN	-18.5	-20.8	-21.1	-2.0
KS	-32.5	-33.1	-33.3	0.3
KY	-19.5	-20.8	-21.4	-2.4
LA	-19.9	-20.2	-20.3	-1.8
MA	-18.3	-21.1	-20.6	-2.5
MD	-19.7	-21.4	-21.2	-2.9
ME	-28.1	-29.2	-29.1	0.0
MI	-16.7	-19.6	-19.8	-2.2
MN	-21.4	-19.8	-19.6	-1.3
MO	-32.3	-32.5	-32.6	0.4
MS	-32.4	-32.0	-31.9	1.1
MT	-16.9	-18.1	-18.0	-1.5
NC	-20.2	-20.9	-21.1	-1.9
ND	-26.0	-28.1	-28.4	1.3
NE	-18.5	-21.2	-21.5	-2.2
NH	-16.9	-18.2	-18.1	-2.2
NJ	-19.5	-21.4	-21.1	-2.5
NM	-21.4	-22.5	-22.5	-2.8
NV	-23.0	-23.4	-23.3	-3.6
NY	-17.0	-20.1	-19.0	-2.5
OH	-17.9	-20.6	-20.9	-2.2
OK	-31.2	-32.9	-34.0	0.9
OR	-20.9	-22.0	-22.0	-3.0
PA	-18.0	-20.3	-20.6	-2.4
RI	-18.9	-21.0	-20.9	-2.4
SC	-21.7	-21.9	-22.0	-2.2
SD	-26.8	-28.4	-28.6	-0.5
TN	-23.4	-22.7	-22.6	-3.0
TX	-19.9	-20.5	-20.5	-2.6
UT	-20.7	-22.5	-22.1	-2.6
VA	-20.8	-21.7	-21.9	-2.2
VT	-16.5	-18.0	-17.8	-2.0
WA	-20.0	-21.1	-21.3	-2.3
WI	-16.4	-18.0	-18.1	-1.2
WV	-30.1	-30.4	-30.3	-4.8
WY	-29.2	-30.1	-30.0	0.7
Avg.	**-21.5**	**-22.8**	**-22.8**	**-2.1**

Table B-8 16-Story Office Building Summary Table for LEC and 10-Year Study Period

State	Percentage Change				State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC		Energy Use	Energy Cost	Carbon	LCC
AK	-8.1	-14.9	-12.9	-0.2	MT	-11.7	-12.5	-12.5	0.4
AL	-23.3	-25.1	-26.0	-1.0	NC	-17.2	-19.1	-19.6	0.4
AR	-18.2	-23.8	-25.7	0.0	ND	-9.9	-13.5	-14.1	0.4
AZ	-19.6	-20.5	-20.8	0.0	NE	-15.2	-20.2	-20.7	0.8
CA	-19.8	-21.8	-21.0	-0.1	NH	-11.3	-12.3	-12.2	-0.6
CO	-15.7	-21.2	-21.7	0.1	NJ	-16.0	-21.0	-20.1	-0.1
CT	-15.2	-21.6	-19.6	-0.9	NM	-18.9	-21.7	-21.7	0.3
DE	-16.0	-19.4	-19.9	-1.0	NV	-12.5	-16.0	-15.1	0.7
FL	-17.6	-18.5	-18.5	-0.2	NY	-13.9	-18.7	-16.9	-0.6
GA	-16.5	-18.4	-19.1	0.5	OH	-14.4	-19.5	-20.2	0.5
HI	-16.4	-16.4	-16.4	-0.6	OK	-17.3	-23.0	-26.9	0.3
IA	-13.0	-16.2	-16.6	0.6	OR	-17.8	-20.9	-21.1	1.0
ID	-15.3	-17.7	-17.8	0.9	PA	-14.4	-18.9	-19.6	0.4
IL	-13.9	-19.8	-19.8	0.2	RI	-15.3	-20.0	-19.7	-0.3
IN	-15.0	-19.7	-20.4	0.6	SC	-12.1	-15.5	-15.9	1.0
KS	-17.1	-21.6	-23.1	0.3	SD	-10.1	-13.2	-13.6	0.2
KY	-16.2	-19.3	-20.7	0.7	TN	-12.3	-15.0	-15.4	0.8
LA	-16.6	-18.3	-18.8	0.7	TX	-16.8	-19.1	-19.1	-0.1
MA	-14.4	-20.2	-19.0	-0.3	UT	-17.5	-21.7	-20.8	0.6
MD	-16.0	-20.1	-19.7	-0.3	VA	-18.0	-20.6	-21.1	0.4
ME	-13.9	-15.9	-15.8	-0.7	VT	-11.3	-12.3	-12.2	-0.4
MI	-12.6	-16.9	-17.5	0.2	WA	-16.2	-19.1	-19.8	1.4
MN	-8.7	-7.8	-7.7	1.0	WI	-10.9	-11.9	-12.0	0.3
MO	-16.3	-20.0	-22.2	0.9	WV	-16.9	-19.1	-23.0	0.9
MS	-27.3	-24.8	-24.7	-0.5	WY	-12.8	-16.2	-16.1	0.1
					Avg.	**-15.3**	**-18.3**	**-18.5**	**0.3**

Table B-9 1-Story Retail Store Summary Table for LEC and 10-Year Study Period

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
AK	-26.3	-27.3	-26.8	-0.2
AL	-35.1	-35.6	-35.9	-0.9
AR	-29.8	-31.8	-32.5	-1.7
AZ	-31.6	-32.4	-32.6	-1.8
CA	-16.1	-17.8	-17.1	0.0
CO	-28.4	-32.0	-32.4	-2.0
CT	-12.3	-16.9	-15.5	-1.7
DE	-14.2	-16.7	-17.1	-0.8
FL	-17.9	-18.2	-18.2	-0.7
GA	-15.5	-16.5	-16.8	0.5
HI	-22.3	-22.3	-22.3	-3.1
IA	-14.3	-17.2	-17.6	0.6
ID	-14.2	-16.3	-16.3	1.2
IL	-12.5	-16.9	-16.9	-0.4
IN	-13.5	-16.8	-17.4	0.5
KS	-30.6	-33.9	-35.1	1.0
KY	-14.9	-17.2	-18.3	0.5
LA	-15.0	-15.5	-15.7	0.7
MA	-11.8	-16.1	-15.2	0.1
MD	-14.3	-17.3	-17.0	-0.1
ME	-31.7	-33.2	-33.1	-1.2
MI	-12.6	-16.0	-16.4	-0.3
MN	-27.3	-23.9	-23.5	-0.8
MO	-31.3	-33.5	-34.8	1.7
MS	-40.6	-38.8	-38.8	-0.3
MT	-16.0	-17.7	-17.5	0.1
NC	-15.8	-17.2	-17.6	0.1
ND	-31.8	-33.4	-33.7	0.6
NE	-12.5	-16.8	-17.2	0.8
NH	-15.9	-17.8	-17.5	-0.9
NJ	-13.9	-17.4	-16.7	0.1
NM	-15.6	-18.9	-18.9	0.1
NV	-21.0	-21.9	-21.7	-0.6
NY	-12.4	-16.4	-14.9	-0.6
OH	-12.5	-16.1	-16.6	-0.5
OK	-30.5	-32.6	-34.0	1.9
OR	-13.2	-15.3	-15.4	0.8
PA	-12.3	-15.4	-15.9	0.1
RI	-12.4	-15.8	-15.6	-1.5
SC	-20.2	-20.5	-20.5	0.2
SD	-29.9	-33.5	-34.0	-0.9
TN	-23.1	-22.6	-22.5	-0.4
TX	-15.3	-16.5	-16.5	0.0
UT	-13.0	-17.3	-16.3	1.2
VA	-16.1	-18.2	-18.7	0.5
VT	-15.7	-17.5	-17.3	-0.8
WA	-12.3	-13.9	-14.3	1.1
WI	-15.9	-18.0	-18.1	-1.1
WV	-30.7	-31.6	-32.9	-1.8
WY	-30.5	-34.0	-34.0	0.4
Avg.	**-18.9**	**-20.9**	**-21.0**	**-0.1**

Table B-10 1-Story Restaurant Summary Table for LEC and 10-Year Study Period

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
AK	-33.4	-40.1	-37.9	1.0
AL	-43.9	-46.5	-47.7	-3.4
AR	-39.8	-44.8	-46.5	-10.3
AZ	-41.4	-43.6	-44.2	-5.2
CA	-34.1	-37.5	-36.2	-5.2
CO	-40.2	-46.3	-47.0	-7.4
CT	-24.1	-33.6	-30.6	-4.4
DE	-27.7	-32.2	-33.0	-8.5
FL	-30.5	-31.5	-31.6	-5.3
GA	-30.0	-32.7	-33.6	-4.9
HI	-34.8	-34.8	-34.8	-6.3
IA	-23.7	-30.3	-31.2	-4.4
ID	-26.0	-30.8	-30.9	-2.7
IL	-23.3	-32.6	-32.6	-4.5
IN	-24.8	-31.9	-33.1	-4.3
KS	-40.8	-46.4	-48.3	-1.2
KY	-27.9	-32.3	-34.3	-5.4
LA	-29.3	-31.3	-31.9	-6.0
MA	-23.8	-32.5	-30.7	-3.7
MD	-27.7	-33.5	-32.9	-9.0
ME	-43.6	-45.6	-45.5	-2.6
MI	-22.1	-30.3	-31.4	-3.0
MN	-37.9	-36.3	-36.1	-5.0
MO	-39.1	-43.9	-46.8	-3.3
MS	-46.0	-47.7	-47.7	-1.9

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
MT	-24.1	-28.9	-28.4	-1.4
NC	-30.2	-33.0	-33.8	-4.8
ND	-41.8	-44.2	-44.6	-0.2
NE	-24.2	-32.6	-33.5	-3.9
NH	-24.3	-29.0	-28.3	-4.6
NJ	-27.3	-34.1	-32.8	-6.3
NM	-31.4	-36.6	-36.6	-4.3
NV	-35.1	-38.6	-37.7	-6.0
NY	-21.7	-31.5	-27.7	-4.3
OH	-23.3	-31.4	-32.6	-3.4
OK	-39.7	-45.1	-48.8	-3.1
OR	-28.5	-33.0	-33.4	-4.5
PA	-23.7	-30.4	-31.6	-3.4
RI	-25.0	-31.8	-31.4	-3.8
SC	-32.0	-34.7	-35.1	-4.2
SD	-39.0	-43.6	-44.2	-3.0
TN	-32.9	-35.6	-36.1	-7.7
TX	-29.8	-33.2	-33.2	-5.9
UT	-27.1	-34.7	-32.9	-3.8
VA	-30.3	-34.0	-34.8	-5.4
VT	-23.6	-28.5	-27.9	-4.3
WA	-26.4	-30.6	-31.6	-3.9
WI	-23.6	-28.7	-29.1	-3.3
WV	-39.3	-41.8	-45.3	-6.4
WY	-42.3	-46.2	-46.1	1.3
Avg.	**-30.7**	**-35.4**	**-35.6**	**-4.2**

C Total Changes from Nationwide Adoption of the LEC Design

Table C-1 Total Reductions by State for Adoption of the LEC Design, 10-Year

State	Code	Average Annual New Floor Area 1000 m^2 (1000 ft^2)	Energy Use (GWh)	Energy Costs ($million)	Carbon (1000 tCO_2e)	LCC ($million)
FL	2007	16 542 (178 061)	3790.5	333.0	3230.0	151.3
TX	2007	14 446 (155 495)	2831.6	235.0	2630.0	106.8
CA	2007	14 492 (155 996)	2543.2	306.0	1146.0	124.9
AZ	1999	4758 (51 214)	1857.5	136.0	1255.0	79.1
GA	2007	7240 (77 934)	1348.0	103.0	1018.0	28.5
IL	2007	6929 (74 579)	1212.7	124.0	1344.0	31.4
CO	2001	3292 (35 437)	1112.9	72.7	1126.0	59.7
AL	1999	2254 (24 266)	1050.6	84.9	908.8	37.0
NY	2007	6071 (65 346)	1037.6	133.0	560.8	37.1
MO	None	2358 (25 383)	984.7	56.9	1001.0	2.7
VA	2007	4499 (48 426)	871.3	60.5	695.0	14.0
NC	2007	4437 (47 758)	827.9	56.2	585.0	20.3
OH	2007	4907 (52 814)	826.8	74.1	837.6	33.9
MN	2004	2329 (25 068)	816.7	33.5	443.8	12.4
TN	2004	3272 (35 219)	807.8	58.7	626.8	28.1
PA	2007	4661 (50 170)	764.9	63.9	628.9	18.2
NV	2004	3516 (37 844)	709.0	59.7	327.2	17.9
MS	1999	1251 (13 465)	689.6	46.3	465.2	14.8
IN	2007	3663 (39 425)	656.9	49.8	652.7	13.3
MD	2007	3385 (36 433)	622.2	62.4	448.9	28.8
OK	1999	1590 (17 115)	598.1	35.4	678.9	0.7
SC	2004	2718 (29 257)	594.5	43.8	412.4	12.2
NJ	2007	3476 (37 421)	581.6	72.7	436.8	20.8
WA	2007	3710 (39 937)	525.0	32.3	266.7	-11.5
MI	2007	2964 (31 905)	511.9	40.4	490.9	17.0
WI	2007	2386 (25 679)	491.0	33.2	383.7	14.8
KS	None	1077 (11 590)	438.6	28.6	436.0	2.3
AR	2001	1186 (12 762)	426.1	28.6	372.7	20.4
MA	2007	2579 (27 760)	403.8	56.0	277.4	12.8
KY	2007	1956 (21 050)	378.0	24.6	341.2	9.8
LA	2007	1700 (18 294)	324.6	20.8	269.7	3.2
UT	2007	1718 (18 492)	286.6	18.8	144.3	5.4
IA	2007	1447 (15 573)	283.7	17.6	256.4	4.0
OR	2007	1745 (18 788)	261.4	17.4	146.1	-0.4
CT	2007	1445 (15 549)	232.0	35.1	160.6	19.7
ME	None	497 (5349)	216.6	18.0	113.3	6.4
WV	2001	479 (5159)	177.2	9.7	161.3	7.1
NE	2007	920 (9900)	170.8	11.1	166.6	1.4
NM	2007	817 (8790)	153.7	11.7	146.0	5.5
ID	2007	802 (8629)	139.9	7.6	69.9	1.5
HI	2004	536 (5773)	138.4	23.9	123.8	13.9
SD	None	303 (3262)	122.3	6.5	98.2	2.4
NH	2007	553 (5948)	108.0	10.9	59.2	5.8
ND	None	229 (2464)	104.5	4.8	75.8	0.0
AK	1999	290 (3116)	99.4	9.8	58.4	2.4
WY	1999	230 (2477)	76.6	5.3	45.3	0.7
DE	2007	344 (3700)	60.1	6.5	45.1	4.5
RI	2007	335 (3604)	55.3	6.6	37.5	3.1
MT	2007	238 (2562)	52.5	2.9	24.1	0.5
VT	2007	200 (2147)	37.3	3.4	20.7	1.4

Table C-2 Energy Use Reduction per Unit of Floor Area from Adoption of the LEC Design, 10-Year

State	Code	Average Annual New Floor Area 1000 m^2 (1000 ft^2)	Energy Savings (GWh)	kWh/m^2	kWh/ft^2
MS	None	1251 (13 465)	689.6	551	51
AL	None	2254 (24 266)	1050.6	466	43
ND	None	229 (2464)	104.5	456	42
ME	None	497 (5349)	216.6	436	40
MO	None	2358 (25 383)	984.7	418	39
KS	None	1077 (11 590)	438.6	407	38
SD	None	303 (3262)	122.3	404	37
AZ	None	4758 (51 214)	1857.5	390	36
OK	None	1590 (17 115)	598.1	376	35
WV	2001	479 (5159)	177.2	370	34
AR	2001	1186 (12 762)	426.1	359	33
MN	2004	2329 (25 068)	816.7	351	33
AK	None	290 (3116)	99.4	343	32
CO	2001	3292 (35 437)	1112.9	338	31
WY	None	230 (2477)	76.6	333	31
HI	2004	536 (5773)	138.4	258	24
TN	2004	3272 (35 219)	807.8	247	23
FL	2007	16 542 (178 061)	3790.5	229	21
MT	2007	238 (2562)	52.5	221	20
SC	2004	2718 (29 257)	594.5	219	20
NV	2004	3516 (37 844)	709	202	19
WI	2007	2386 (25 679)	491	206	19
IA	2007	1447 (15 573)	283.7	196	18
KY	2007	1956 (21 050)	378	193	18
LA	2007	1700 (18 294)	324.6	191	18
NH	2007	553 (5948)	108	195	18
TX	2007	14 446 (155 495)	2831.6	196	18
VA	2007	4499 (48 426)	871.3	194	18
GA	2007	7240 (77 934)	1348	186	17
IN	2007	3663 (39 425)	656.9	179	17
MD	2007	3385 (36 433)	622.2	184	17
NC	2007	4437 (47 758)	827.9	187	17
NE	2007	920 (9900)	170.8	186	17
NM	2007	817 (8790)	153.7	188	17
VT	2007	200 (2147)	37.3	187	17
CA	2007	14 492 (155 996)	2543.2	175	16
DE	2007	344 (3700)	60.1	175	16
ID	2007	802 (8629)	139.9	174	16
IL	2007	6929 (74 579)	1212.7	175	16
MI	2007	2964 (31 905)	511.9	173	16
NJ	2007	3476 (37 421)	581.6	167	16
NY	2007	6071 (65 346)	1037.6	171	16
OH	2007	4907 (52 814)	826.8	168	16
MA	2007	2579 (27 760)	403.8	157	15
PA	2007	4661 (50 170)	764.9	164	15
RI	2007	335 (3604)	55.3	165	15
UT	2007	1718 (18 492)	286.6	167	15
CT	2007	1445 (15 549)	232	161	15
OR	2007	1745 (18 788)	261.4	150	14
WA	2007	3710 (39 937)	525	142	13

Table C-3 Life-Cycle Cost Reductions per Unit of New Floor Area from Adoption of the LEC Design, 10-Year

State	Code	kWh/m^2	LCC Savings ($million)	LCC Savings ($/m^2)	LCC Savings ($/ft^2)
HI	2004	258	13.9	25.93	2.41
CO	2001	338	59.7	18.13	1.68
AR	2001	359	20.4	17.20	1.60
AZ	1999	390	79.1	16.62	1.54
AL	1999	466	37.0	16.42	1.53
WV	2001	370	7.1	14.82	1.38
CT	2007	161	19.7	13.63	1.27
DE	2007	175	4.5	13.08	1.22
ME	None	436	6.4	12.88	1.20
MS	1999	551	14.8	11.83	1.10
NH	2007	195	5.8	10.49	0.97
RI	2007	165	3.1	9.25	0.86
FL	2007	229	151.3	9.15	0.85
CA	2007	175	124.9	8.62	0.80
TN	2004	247	28.1	8.59	0.80
MD	2007	184	28.8	8.51	0.79
AK	1999	343	2.4	8.28	0.77
SD	None	404	2.4	7.92	0.74
TX	2007	196	106.8	7.39	0.69
VT	2007	187	1.4	7.00	0.65
OH	2007	168	33.9	6.91	0.64
NM	2007	188	5.5	6.73	0.63
WI	2007	206	14.8	6.20	0.58
NY	2007	171	37.1	6.11	0.57
NJ	2007	167	20.8	5.98	0.56
MI	2007	173	17.0	5.74	0.53
MN	2004	351	12.4	5.32	0.49
NV	2004	202	17.9	5.09	0.47
KY	2007	193	9.8	5.01	0.47
MA	2007	157	12.8	4.96	0.46
NC	2007	187	20.3	4.58	0.43
IL	2007	175	31.4	4.53	0.42
SC	2004	219	12.2	4.49	0.42
GA	2007	186	28.5	3.94	0.37
PA	2007	164	18.2	3.90	0.36
IN	2007	179	13.3	3.63	0.34
UT	2007	167	5.4	3.14	0.29
VA	2007	194	14.0	3.11	0.29
WY	1999	333	0.7	3.04	0.28
IA	2007	196	4.0	2.76	0.26
KS	None	407	2.3	2.14	0.20
MT	2007	221	0.5	2.10	0.20
LA	2007	191	3.2	1.88	0.17
ID	2007	174	1.5	1.87	0.17
NE	2007	186	1.4	1.52	0.14
MO	None	418	2.7	1.15	0.11
OK	1999	376	0.7	0.44	0.04
ND	None	456	0.0	0.00	0.00
OR	2007	150	-0.4	-0.23	-0.02
WA	2007	142	-11.5	-3.10	-0.29

Table C-4 Energy Cost Reduction per kWh of Energy Use Reduction from Adoption of the LEC Design, 10-Year

State	Code	Offset* (%)	Electricity Rate ($/kWh)	Natural Gas Rate ($/kWh)	Energy Cost Reduction ($/kWh)
HI	2004	0.0%	0.22	0.09	$0.17
CT	2007	18.5%	0.17	0.03	$0.15
MA	2007	18.0%	0.15	0.04	$0.14
NJ	2007	17.4%	0.14	0.03	$0.13
NY	2007	7.6%	0.16	0.03	$0.13
CA	2007	13.0%	0.13	0.02	$0.12
RI	2007	16.8%	0.14	0.04	$0.12
DE	2007	17.4%	0.12	0.05	$0.11
AK	1999	-24.9%	0.14	0.03	$0.10
IL	2007	11.6%	0.11	0.03	$0.10
MD	2007	13.3%	0.12	0.03	$0.10
NH	2007	-20.4%	0.15	0.04	$0.10
FL	2007	4.0%	0.11	0.03	$0.09
OH	2007	15.3%	0.10	0.03	$0.09
VT	2007	-18.6%	0.13	0.04	$0.09
AL	1999	1.8%	0.10	0.04	$0.08
GA	2007	10.4%	0.09	0.03	$0.08
IN	2007	13.6%	0.08	0.03	$0.08
ME	None	-27.5%	0.13	0.04	$0.08
MI	2007	3.7%	0.09	0.03	$0.08
NM	2007	16.0%	0.08	0.02	$0.08
NV	2004	1.1%	0.11	0.03	$0.08
PA	2007	17.2%	0.10	0.03	$0.08
TX	2007	9.2%	0.10	0.02	$0.08
AR	2001	17.2%	0.08	0.03	$0.07
AZ	1999	2.2%	0.09	0.04	$0.07
CO	2001	8.6%	0.08	0.02	$0.07
KS	None	2.6%	0.08	0.03	$0.07
KY	2007	11.1%	0.08	0.03	$0.07
MS	1999	-20.7%	0.10	0.03	$0.07
NC	2007	11.3%	0.08	0.03	$0.07
OR	2007	18.8%	0.07	0.03	$0.07
SC	2004	9.1%	0.09	0.03	$0.07
TN	2004	-9.4%	0.10	0.03	$0.07
UT	2007	21.7%	0.07	0.02	$0.07
VA	2007	12.4%	0.08	0.03	$0.07
WI	2007	-25.9%	0.10	0.03	$0.07
WY	1999	6.9%	0.07	0.02	$0.07
IA	2007	-1.0%	0.08	0.02	$0.06
LA	2007	7.7%	0.08	0.03	$0.06
MO	None	3.0%	0.07	0.03	$0.06
MT	2007	-38.9%	0.08	0.03	$0.06
NE	2007	9.6%	0.07	0.02	$0.06
OK	1999	17.2%	0.07	0.03	$0.06
WA	2007	19.4%	0.07	0.04	$0.06
ID	2007	8.4%	0.06	0.03	$0.05
ND	None	-33.0%	0.07	0.02	$0.05
SD	None	-14.6%	0.07	0.02	$0.05
WV	2001	3.9%	0.07	0.04	$0.05
MN	2004	-121.2%	0.08	0.02	$0.04

Table C-5 Carbon Reduction per GWh of Energy Use Reduction from Adoption of the LEC Design, 10-Year

State	Code	Offset* (%)	CO_2e Emissions Rate for Electricity (t/GWh)	CO_2e Emissions Rate for Natural Gas (t/GWh)	CO_2e Reduction (t/GWh)
OK	1999	17.2%	970.1	241	1135
IL	2007	11.6%	992.9	241	1108
MO	None	3.0%	984.2	241	1016
OH	2007	15.3%	874.8	241	1013
CO	2001	8.6%	993.6	241	1012
IN	2007	13.6%	874.8	241	994
KS	None	2.6%	971.1	241	994
NE	2007	9.6%	891.8	241	975
MI	2007	3.7%	908.8	241	959
NM	2007	16.0%	835.1	241	950
TX	2007	9.2%	858.4	241	929
WV	2001	3.9%	874.8	241	910
IA	2007	-1.0%	891.8	241	904
KY	2007	11.1%	819.0	241	903
HI	2004	0.0%	835.2	241	895
AR	2001	17.2%	756.1	241	875
AL	1999	1.8%	847.4	241	865
FL	2007	4.0%	826.1	241	852
LA	2007	7.7%	780.0	241	831
PA	2007	17.2%	708.0	241	822
SD	None	-14.6%	891.8	241	803
VA	2007	12.4%	723.1	241	798
WI	2007	-25.9%	905.1	241	781
TN	2004	-9.4%	819.0	241	776
GA	2007	10.4%	847.4	241	755
NJ	2007	17.4%	652.5	241	751
DE	2007	17.4%	652.5	241	750
ND	None	-33.0%	891.8	241	725
MD	2007	13.3%	652.5	241	721
NC	2007	11.3%	647.3	241	707
SC	2004	9.1%	647.3	241	694
CT	2007	18.5%	598.8	241	692
MA	2007	18.0%	598.8	241	687
RI	2007	16.8%	598.8	241	678
AZ	1999	2.2%	801.4	241	675
MS	1999	-20.7%	759.1	241	675
WY	1999	6.9%	660.7	241	591
AK	1999	-24.9%	663.3	241	588
OR	2007	18.8%	493.6	241	559
VT	2007	-18.6%	598.8	241	555
NH	2007	-20.4%	598.8	241	548
MN	2004	-121.2%	891.8	241	543
NY	2007	7.6%	513.7	241	540
ME	None	-27.5%	598.8	241	523
WA	2007	19.4%	493.6	241	508
UT	2007	21.7%	493.6	241	503
ID	2007	8.4%	493.6	241	500
NV	2004	1.1%	493.6	241	461
MT	2007	-38.9%	573.3	241	459
CA	2007	13.0%	497.3	241	450

D Percentage Changes by Building Type for the Nationwide Adoption of the *ASHRAE 90.1-2007* Design

Table D-1 4-Story Apartment Building Summary Table for *ASHRAE 90.1-2007* and 10-Year Study Period

State	Percentage Change Energy Use	Energy Cost	Carbon	LCC	State	Percentage Change Energy Use	Energy Cost	Carbon	LCC
AK	-5.6	-20.2	-15.3	-2.3	MS	-25.5	-29.7	-29.9	-3.6
AL	-24.3	-27.9	-29.8	-3.6	ND	-8.5	-18.8	-20.9	-1.6
AR	-18.7	-24.5	-26.6	-2.5	NV	-4.3	-3.7	-3.9	-0.4
AZ	-14.3	-15.9	-16.3	-1.8	OK	-17.4	-23.5	-28.0	-2.0
CO	-12.7	-22.0	-23.1	-1.9	SC	-4.7	-6.1	-6.3	-0.6
HI	-2.7	-2.7	-2.7	-0.5	SD	-12.5	-21.9	-23.3	-2.2
KS	-15.7	-23.0	-25.6	-2.2	TN	-3.7	-3.4	-3.3	-0.4
ME	-11.5	-21.3	-20.6	-2.8	WV	-15.9	-19.0	-25.3	-1.7
MN	-4.9	-3.5	-3.3	-0.5	WY	-13.7	-24.0	-23.9	-2.0
MO	-16.0	-21.6	-25.3	-1.8	**Avg.**	**-11.4**	**-16.7**	**-17.4**	**-1.7**

Table D-2 6-Story Apartment Building Summary Table for *ASHRAE 90.1-2007* and 10-Year Study Period

State	Percentage Change Energy Use	Energy Cost	Carbon	LCC	State	Percentage Change Energy Use	Energy Cost	Carbon	LCC
AK	-5.5	-20.3	-15.4	-2.2	MS	-25.3	-29.5	-29.7	-3.6
AL	-23.7	-27.6	-29.5	-3.6	ND	-8.5	-18.8	-20.8	-1.6
AR	-18.4	-24.3	-26.4	-2.5	NV	-3.7	-3.2	-3.4	-0.3
AZ	-13.6	-15.3	-15.7	-1.7	OK	-17.0	-23.3	-27.9	-2.1
CO	-12.4	-21.7	-22.8	-1.8	SC	-4.1	-5.9	-6.1	-0.5
HI	-2.5	-2.5	-2.5	-0.4	SD	-12.1	-21.6	-22.9	-2.1
KS	-15.4	-22.7	-25.3	-2.3	TN	-3.1	-2.9	-2.8	-0.3
ME	-11.2	-21.0	-20.3	-2.7	WV	-15.4	-18.6	-24.8	-1.6
MN	-4.4	-3.1	-2.9	-0.4	WY	-13.3	-23.7	-23.6	-1.9
MO	-15.7	-21.2	-24.9	-1.8	**Avg.**	**-11.0**	**-16.3**	**-17.1**	**-1.6**

Table D-3 4-Story Dormitory Summary Table for *ASHRAE 90.1-2007* and 10-Year Study Period

State	Percentage Change				State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC		Energy Use	Energy Cost	Carbon	LCC
AK	-6.5	-21.1	-16.3	-1.8	MS	-29.2	-32.0	-32.1	-1.0
AL	-25.6	-29.4	-31.2	-1.2	ND	-9.3	-20.2	-22.2	1.2
AR	-17.7	-24.5	-26.9	-5.1	NV	-5.0	-3.5	-3.9	-0.7
AZ	-16.4	-16.9	-17.0	-0.1	OK	-16.8	-24.2	-29.4	-0.3
CO	-13.4	-21.8	-22.8	-2.9	SC	-2.0	-4.4	-4.7	-0.5
HI	-2.9	-2.9	-2.9	-0.8	SD	-13.1	-22.7	-24.0	-1.2
KS	-17.2	-24.4	-26.9	0.3	TN	-3.6	-2.8	-2.7	-0.7
ME	-13.1	-22.5	-21.9	-0.2	WV	-16.2	-19.4	-25.1	-2.2
MN	-7.3	-4.7	-4.3	-0.7	WY	-14.9	-24.6	-24.5	0.4
MO	-16.9	-22.6	-26.3	-0.1	**Avg.**	**-12.3**	**-17.2**	**-17.9**	**-0.9**

Table D-4 6-Story Dormitory Summary Table for *ASHRAE 90.1-2007* and 10-Year Study Period

State	Percentage Change				State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC		Energy Use	Energy Cost	Carbon	LCC
AK	-5.1	-19.9	-14.9	-2.6	MS	-27.7	-32.2	-32.4	-4.5
AL	-26.5	-30.5	-32.5	-4.6	ND	-9.0	-18.3	-20.2	-2.1
AR	-19.5	-25.6	-27.8	-3.2	NV	-2.7	-2.6	-2.6	-0.2
AZ	-15.2	-16.7	-17.1	-2.2	OK	-19.3	-25.8	-30.5	-2.9
CO	-10.6	-20.6	-21.8	-2.1	SC	-5.9	-8.0	-8.2	-0.7
HI	-2.3	-2.3	-2.3	-0.4	SD	-9.6	-19.8	-21.3	-2.3
KS	-14.3	-21.9	-24.7	-2.7	TN	-2.1	-2.3	-2.3	-0.2
ME	-10.7	-20.4	-19.7	-3.1	WV	-13.8	-17.2	-23.5	-1.9
MN	-3.6	-2.5	-2.3	-0.3	WY	-10.6	-21.8	-21.7	-2.2
MO	-15.4	-21.3	-25.2	-2.3	**Avg.**	**-10.7**	**-16.3**	**-17.1**	**-2.0**

Table D-5 15-Story Hotel Building Summary Table for *ASHRAE 90.1-2007* and 10-Year Study Period

State	Percentage Change				State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC		Energy Use	Energy Cost	Carbon	LCC
AK	2.7	-12.9	-7.7	-2.1	MS	-25.0	-22.9	-22.8	-3.1
AL	-18.6	-22.4	-24.3	-3.2	ND	-0.4	-10.9	-12.9	-1.6
AR	-9.1	-17.8	-21.0	-2.2	NV	6.0	6.8	6.5	0.6
AZ	-9.2	-8.9	-8.8	-1.3	OK	-7.9	-16.3	-22.5	-1.8
CO	-3.4	-12.8	-13.9	-1.6	SC	7.4	5.0	4.7	0.6
HI	2.1	2.1	2.2	0.3	SD	-3.0	-12.1	-13.4	-1.8
KS	-7.0	-13.6	-15.9	-2.0	TN	5.8	6.7	6.9	0.6
ME	-5.0	-13.6	-13.0	-2.4	WV	-6.7	-9.7	-15.8	-1.4
MN	2.7	4.7	5.0	0.3	WY	-4.0	-14.3	-14.2	-1.8
MO	-7.3	-12.4	-15.8	-1.6	**Avg.**	**-3.2**	**-8.1**	**-8.8**	**-1.2**

Table D-6 2-Story High School Summary Table for *ASHRAE 90.1-2007* and 10-Year Study Period

State	Percentage Change				State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC		Energy Use	Energy Cost	Carbon	LCC
AK	-2.4	-7.1	-5.3	-0.7	MS	-16.8	-17.4	-17.4	-2.3
AL	-12.3	-14.4	-15.6	-1.7	ND	-4.9	-8.1	-8.9	-0.4
AR	-6.4	-10.5	-12.1	-0.7	NV	-3.4	-2.7	-3.0	-0.4
AZ	-10.8	-11.4	-11.6	-1.5	OK	-6.0	-9.8	-13.1	-0.3
CO	-5.0	-8.8	-9.3	-1.1	SC	-1.7	-2.0	-2.1	0.2
HI	-1.0	-1.0	-1.0	-0.1	SD	-5.0	-8.7	-9.4	-0.9
KS	-7.1	-10.3	-11.6	-0.8	TN	-3.1	-2.5	-2.3	-0.4
ME	-4.9	-8.4	-8.2	-0.8	WV	-6.7	-7.9	-10.7	-1.0
MN	-3.4	-2.6	-2.4	-0.5	WY	-5.2	-9.4	-9.3	-0.6
MO	-7.1	-9.4	-11.2	-0.9	**Avg.**	**-5.8**	**-7.7**	**-8.2**	**-0.8**

Table D-7 8-Story Office Building Summary Table for *ASHRAE 90.1-2007* and 10-Year Study Period

State	Percentage Change				State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC		Energy Use	Energy Cost	Carbon	LCC
AK	-6.0	-10.8	-9.5	1.1	MS	-15.8	-14.5	-14.5	3.1
AL	-15.3	-15.3	-15.3	1.1	ND	-10.7	-12.5	-12.8	2.5
AR	-13.8	-14.5	-14.7	-3.9	NV	-3.2	-1.3	-1.8	-0.4
AZ	-8.8	-7.8	-7.6	1.4	OK	-16.0	-16.9	-17.4	2.4
CO	-10.7	-10.6	-10.6	-2.6	SC	-2.6	-2.1	-2.1	-0.7
HI	-1.4	-1.4	-1.4	-0.3	SD	-12.4	-12.9	-12.9	0.7
KS	-16.0	-14.9	-14.6	3.0	TN	-4.0	-1.8	-1.5	-0.8
ME	-12.8	-13.4	-13.3	1.7	WV	-13.3	-12.8	-11.8	-2.8
MN	-5.6	-2.2	-1.9	-0.3	WY	-13.7	-14.0	-14.0	2.2
MO	-16.1	-14.8	-14.1	2.4	**Avg.**	**-9.8**	**-9.5**	**-9.3**	**0.5**

Table D-8 16-Story Office Building Summary Table for *ASHRAE 90.1-2007* and 10-Year Study Period

State	Percentage Change				State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC		Energy Use	Energy Cost	Carbon	LCC
AK	4.0	-3.2	-1.0	-0.4	MS	-14.1	-7.9	-7.6	-0.9
AL	-9.1	-9.4	-9.6	-1.3	ND	2.2	-1.8	-2.4	-0.2
AR	-3.5	-7.9	-9.4	-1.0	NV	5.8	7.0	6.7	0.8
AZ	-1.9	-0.4	0.0	0.0	OK	-2.9	-7.3	-10.4	-0.6
CO	0.3	-2.4	-2.7	-0.3	SC	5.6	3.7	3.5	0.5
HI	3.1	3.1	3.1	0.6	SD	1.2	-1.5	-1.8	-0.2
KS	-1.0	-2.2	-2.7	-0.2	TN	6.4	6.8	6.8	0.8
ME	-2.2	-4.2	-4.1	-0.7	WV	-0.8	-1.5	-2.7	-0.2
MN	3.0	4.7	4.9	0.4	WY	-0.4	-3.8	-3.7	-0.4
MO	-0.7	-1.7	-2.3	-0.1	**Avg.**	**0.5**	**-0.8**	**-0.9**	**-0.1**

Table D-9 1-Story Retail Store Summary Table for *ASHRAE 90.1-2007* and 10-Year Study Period

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
AK	-8.4	-13.9	-12.1	-0.7
AL	-23.7	-23.6	-23.5	-1.2
AR	-17.5	-18.7	-19.1	-2.6
AZ	-19.9	-18.6	-18.3	-1.7
CO	-17.1	-17.3	-17.3	-2.9
HI	-0.5	-0.5	-0.5	0.0
KS	-19.4	-20.2	-20.5	0.2
ME	-16.7	-18.5	-18.4	-0.9
MN	-11.7	-6.9	-6.3	-0.3
MO	-19.5	-19.9	-20.1	0.5

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
MS	-30.5	-27.3	-27.2	-1.3
ND	-15.7	-18.0	-18.4	-0.3
NV	-10.0	-6.4	-7.4	-1.2
OK	-19.1	-20.3	-21.1	1.4
SC	-5.9	-4.9	-4.8	-0.1
SD	-16.1	-18.4	-18.7	-1.1
TN	-8.4	-5.3	-4.9	-0.4
WV	-19.5	-19.4	-19.0	-2.6
WY	-16.9	-18.9	-18.9	-0.9
Avg.	**-15.2**	**-15.1**	**-15.0**	**-0.9**

Table D-10 1-Story Restaurant Summary Table for *ASHRAE 90.1-2007* and 10-Year Study Period

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
AK	-12.4	-17.0	-15.4	2.4
AL	-21.0	-22.1	-22.6	1.5
AR	-16.2	-19.6	-20.7	-3.1
AZ	-16.1	-14.6	-14.2	0.8
CO	-18.6	-18.8	-18.8	-4.5
HI	-2.6	-2.6	-2.6	-0.6
KS	-18.5	-20.1	-20.6	4.9
ME	-22.8	-22.8	-22.8	1.4
MN	-17.0	-10.1	-9.2	-2.2
MO	-16.3	-18.2	-19.3	4.6

State	Percentage Change			
	Energy Use	Energy Cost	Carbon	LCC
MS	-24.8	-23.1	-23.0	3.6
ND	-20.6	-20.8	-20.9	2.9
NV	-11.3	-6.7	-8.1	-1.7
OK	-17.3	-21.0	-23.6	4.2
SC	-2.8	-2.8	-2.8	-0.5
SD	-19.9	-20.9	-21.0	0.3
TN	-4.4	-2.9	-2.6	-0.9
WV	-17.2	-17.8	-18.3	-3.5
WY	-22.4	-22.9	-22.9	1.6
Avg.	**-15.6**	**-15.5**	**-15.6**	**0.4**

E Total Changes from Nationwide Adoption of the *ASHRAE 90.1-2007* Design

Table E-1 Total Reductions by State for Adoption of the *ASHRAE 90.1-2007* Design, 10-Year

State	Code	Average Annual New Floor Area 1000 m^2 (1000 ft^2)	Energy Use (GWh)	Energy Costs ($million)	Carbon (1000 tCO_2e)	LCC ($million)
AZ	None	4758 (51 214)	946.3	62.2	561.7	30.8
NV	2004	3516 (37 844)	117.3	2.9	24.6	6.3
CO	2001	3292 (35 437)	543.0	35.0	541.4	53.9
TN	2004	3272 (35 219)	172.6	6.5	66.1	7.5
SC	2004	2718 (29 257)	92.2	6.5	60.7	2.9
MO	None	2358 (25 383)	524.1	29.1	502.3	1.9
MN	2004	2329 (25 068)	282.7	6.0	70.8	7.3
AL	None	2254 (24 266)	631.6	49.8	527.8	25.7
OK	None	1590 (17 115)	300.5	29.1	502.3	-5.7
MS	None	1251 (13 465)	470.6	28.1	281.2	12.3
AR	2001	1186 (12 762)	204.3	14.4	190.3	17.5
KS	None	1077 (11 590)	229.5	13.9	208.4	-2.9
HI	2004	536 (5773)	12.1	2.1	10.8	2.0
ME	None	497 (5349)	105.5	9.4	58.8	3.3
WV	2001	479 (5159)	96.4	5.0	78.8	7.2
SD	None	303 (3262)	57.5	3.1	47.9	1.4
AK	None	290 (3116)	14.0	4.3	22.0	1.4
WY	None	230 (2477)	34.9	2.6	22.9	0.5
ND	None	229 (2464)	45.7	2.4	37.7	0.0

Table E-2 Energy Use Reduction per Unit of Floor Area from Adoption of the *ASHRAE 90.1-2007* Design, 10-Year

State	Code	Average Annual New Floor Area 1000 m^2 (1000 ft^2)	Energy Savings (GWh)	kWh/m^2	kWh/ft^2
MS	None	1251 (13 465)	470.6	376	35
AL	None	2254 (24 266)	631.6	280	26
MO	None	2358 (25 383)	524.1	222	21
KS	None	1077 (11 590)	229.5	213	20
ME	None	497 (5349)	105.5	212	20
WV	2001	479 (5159)	96.4	201	19
ND	None	229 (2464)	45.7	200	19
AZ	None	4758 (51 214)	946.3	199	18
SD	None	303 (3262)	57.5	190	18
OK	None	1590 (17 115)	300.5	189	18
AR	2001	1186 (12 762)	204.3	172	16
CO	2001	3292 (35 437)	543.0	165	15
WY	None	230 (2477)	34.9	152	14
MN	2004	2329 (25 068)	282.7	121	11
TN	2004	3272 (35 219)	172.6	53	5
AK	None	290 (3116)	14.0	48	4
SC	2004	2718 (29 257)	92.2	34	3
NV	2004	3516 (37 844)	117.3	33	3
HI	2004	536 (5773)	12.1	23	2

Table E-3 Life-Cycle Cost Reductions per Unit of New Floor Area from Adoption of the *ASHRAE 90.1-2007* Design, 10-Year

State	Code	Energy Use Savings (kWh/m^2)	Electricity Rate ($/kWh)	LCC Savings ($million)	LCC Savings ($\$/m^2$)	LCC Savings ($\$/ft^2$)
CO	2001	165	0.08	53.9	16.37	1.52
WV	2001	201	0.07	7.2	15.03	1.40
AR	2001	172	0.08	17.5	14.76	1.37
AL	None	280	0.10	25.7	11.40	1.06
MS	None	376	0.10	12.3	9.83	0.91
ME	None	212	0.13	3.3	6.64	0.62
AZ	None	199	0.09	30.8	6.47	0.60
AK	None	48	0.14	1.4	4.83	0.45
SD	None	190	0.07	1.4	4.62	0.43
HI	2004	12	0.22	2.0	3.73	0.35
MN	2004	121	0.08	7.3	3.13	0.29
TN	2004	53	0.10	7.5	2.29	0.21
WY	None	152	0.07	0.5	2.17	0.20
NV	2004	33	0.11	6.3	1.79	0.17
SC	2004	34	0.09	2.9	1.07	0.10
MO	None	222	0.07	1.9	0.81	0.07
ND	None	200	0.07	0.0	0.00	0.00
KS	None	213	0.08	-2.9	-2.69	-0.25
OK	None	189	0.07	-5.7	-3.58	-0.33

Table E-4 Energy Cost Reduction per kWh of Energy Use Reduction from Adoption of the *ASHRAE 90.1-2007* Design, 10-Year

State	Code	Weighted Offset (%)	Electricity Rate* ($/kWh)	Electricity Rate* ($/kWh)	Energy Cost Reduction ($/MWh)
AK	None	66.2 %	0.14	0.03	307
HI	2004	0.0 %	0.22	0.09	174
OK	None	24.4 %	0.07	0.03	97
ME	None	-14.7 %	0.13	0.04	89
AL	None	-3.5 %	0.10	0.04	79
WY	None	17.2 %	0.07	0.02	74
SC	2004	5.0 %	0.09	0.03	70
AR	2001	24.1 %	0.08	0.03	70
AZ	None	-7.3 %	0.09	0.04	66
CO	2001	6.6 %	0.08	0.02	64
KS	None	-7.6 %	0.08	0.03	61
MS	None	-59.4 %	0.10	0.03	60
MO	None	-4.6 %	0.07	0.03	56
SD	None	-4.1 %	0.07	0.02	54
ND	None	-8.8 %	0.07	0.02	53
WV	2001	-10.1 %	0.07	0.04	52
TN	2004	-282.3 %	0.10	0.03	38
NV	2004	-230.6 %	0.11	0.03	25
MN	2004	-3113.8 %	0.08	0.02	21

Table E-5 Carbon Reduction per GWh of Energy Use Reduction from Adoption of the *ASHRAE 90.1-2007* Design, 10-Year

State	Code	Weighted Offset (%)	CO2e Emissions Rate for Electricity* ($/kWh)	CO2e Emissions Rate for Natural Gas* ($/kWh)	Carbon Emissions Reduction (tCO_2e/GWh)
OK	None	24.4 %	970	241	1672
AK	None	66.2 %	663	241	1571
CO	2001	6.6 %	994	241	997
MO	None	-4.6 %	984	241	958
AR	2001	24.1 %	756	241	931
KS	None	-7.6 %	971	241	908
HI	2004	0.0 %	835	241	893
AL	None	-3.5 %	847	241	836
SD	None	-4.1 %	892	241	833
ND	None	-8.8 %	892	241	825
WV	2001	-10.1 %	875	241	817
SC	2004	5.0 %	647	241	658
WY	None	17.2 %	661	241	656
MS	None	-59.4 %	759	241	598
AZ	None	-7.3 %	801	241	594
ME	None	-14.7 %	599	241	557
TN	2004	-282.3 %	819	241	383
MN	2004	-3113.8 %	892	241	250
NV	2004	-230.6 %	494	241	210