# BUILDING ENERGY CODES AND THEIR IMPACT ON GREENHOUSE GAS EMISSIONS IN THE UNITED STATES

by

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# Abstract

The purpose of this study is to identify and explore relationships between the building industry, building energy usage, and how both the industry and the energy usage correspond to greenhouse gas (GHG) emissions in the United States. Building energy codes seek to reduce energy usage and, subsequently, GHG emissions. This study specifically seeks to determine the impact that most current U.S. building energy codes could have on national GHG emissions if widespread adoption and enforcement of those codes were a reality.

The report initially presents necessary background information about GHG emissions is first discussed. This establishes the current state of global GHG emissions, the position of the U.S. within the global scale, and what portion of the contribution can be attributed to the building industry. The report also describes the current issues and benefits of building energy codes. An overview of building energy codes evaluation is included, with explanation of the energy analysis used to determine the effectiveness of new building energy codes.

In order to determine how to improve the building energy code system, an analysis of ANSI/ASHRAE/IES Standard 90.1-2013 (equivalent to 2015 IECC, the most recent standard available) is conducted to reveal unrealized GHG emission reductions that are expected with adoption and compliance to the newest code. Standard 90.1-2013 is analyzed due to the national popularity of the code relative to other building energy codes. This analysis includes compilation of energy usage intensity, square footage, and current code adoption data throughout the United States. Results showed that the excess GHG emission savings from enhanced adoption and compliance was not significant on a national scale. However, in terms of GHG emissions currently saved by building energy codes, the extra savings becomes more significant, proving that increased adoption and compliance is a worthwhile pursuit. Recommendations are then made for how to increase adoption and compliance. This information will give policymakers improved understanding of the current state of the industry when crafting laws regarding GHG emissions and building energy codes. Furthermore, findings from this study could benefit specific states that are attempting to lower GHG emissions.

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# Chapter 1 - Greenhouse Gas Emissions and their Impact on the Building Industry

Greenhouse gases (GHGs) and their impact on the environment have been constant subjects of controversy over the last several decades. The validity of theories about GHG's influence on the environment has been continuously debated. The current widely accepted assertion that GHGs negatively affect the environment has led to the enactment of several worldwide policies to reduce the impact of GHGs. These policies span multiple industries, including power, transportation, agriculture, and commercial and residential construction. However, climate analysts have questioned the effectiveness of these policies. While the exact effectiveness of GHG control policies vary from country to country, policies in the United States (U.S.) have not been stringent enough to achieve emissions reduction goals established by current and previous presidents, including the Obama and Clinton administrations. Debate continues about which industry (if any) is the primary contributor to GHG emissions in the U.S., as well as which policies would maximize the achievement of these goals. Regardless of which industry is the leading contributor to GHG emissions, reduction measures throughout all industries must be improved in order for the U.S. to begin meeting policy goals for climate change. The commercial and residential building industry's indirect production of emissions through electrical energy and heating fuel usage is often overlooked during discussion of national GHG emission standards. Emissions produced during the construction process are often completely disregarded because identification of direct sources of emissions, such as the power and transportation industries, is more apparent. However, as shown in this paper, the building industry has unmatched opportunity for impacting national GHG reform efforts.

## What are Greenhouse Gases?

A GHG refers to "any gas in the atmosphere which absorbs and re-emits heat" similar to the process that occurs within a greenhouse (Brander, 2012). The most common GHGs within Earth's atmosphere are water vapor ($H_2O$), carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), and ozone ($O_3$). In the most recent measurements from 2014, global atmospheric concentrations of $CO_2$, $CH_4$, and $N_2O$ in parts per million (ppm) were 398.55, 1.84, and 0.33 (Environmental Protection Agency [EPA], 2015, June). In comparison, the global atmospheric concentration of $H_2O$ varies between 10,000-20,000 ppm (Singer, 2015). The greenhouse effect resulting from naturally-occurring GHGs is necessary for life on Earth because it maintains a habitable temperature on the planet. However, accelerated human-influenced GHG production, such as the burning of fossil fuels, is partially causing (according to overwhelming scientific evidence) excessive heating of Earth's atmosphere and surface, a phenomena known as global warming (Brander, 2012).

The ultimate goal of GHG reduction measures is to keep the annual mean global temperature rise below 2.0 °C when compared to 1961-1990 levels (an annual mean global temperature of 14.0 °C) in order to avoid "tipping points" of climate change (National Center for Atmospheric Research [NCAR], 2014). These tipping points refer to "critical thresholds at which the future state of a system can be qualitatively altered by a small change in forcing" (Lenton et al., 2008). Many climate systems, or tipping elements, on Earth have tipping points. Five of these tipping elements have been identified as near to their tipping points, thereby posing the highest threat to irreversible climate change. These critical tipping elements are the Greenland and West Antarctic ice sheets which are plagued by melting ice and rising sea levels, the Amazon rainforest which is undergoing massive vegetation dieback, the Sahel and West African Monsoon which have experienced droughts and warming, and the Indian Summer Monsoon which is being disrupted by an atmospheric brown cloud (a mixture of soot and reflecting sulfate) (Lenton et al., 2008).

The 2 °C global threshold is only a general guideline because various regional tipping points cannot be directly linked to a global mean temperature change. However, a rise between 2.0 and 4.0 °C "gives a >16% probability of crossing at least 1 of 5 tipping points, which rises to >56% for a >4.0 °C committed warming" (Lenton et al., 2008). In terms of current projections of temperature rise, a study done by Smith et al. (2009) demonstrated that the likely range (66-90%) for "global temperature increase by 2100 for the lowest emissions scenario is 1.1 °C – 2.9 °C, whereas the likely range for the highest scenario is 2.4 °C – 6.4 °C". Since 2000, the projection for global GHG emissions has surpassed the previous highest temperature rise scenario predicted, resulting in potential temperature rises that will exceed the ranges previously listed (Smith, 2009). Based on these predictions, increasing GHG reduction measures must be a high priority in order to avoid irreversible climate change.

Accurate understanding of climate change requires discussion of the types of GHGs and their energy absorption ratings. As stated previously, the most common GHG emitted is $CO_2$. Since it is the most common, several reports and studies only refer to GHG emissions in terms of $CO_2$; however, $CO_2$ by itself does not constitute the whole GHG picture. The committee responsible for the Kyoto Protocol (discussed in the next section) created an index, the Global Warming Potential (GWP), to compare the most common GHGs (Brander, 2012). GWP shows how much energy 1 ton of gas absorbs over a given time frame compared to $CO_2$. Although given time frame can vary, the most common period used is 100 years. A GHG with a higher energy absorption rating has a higher GWP. GWP values for the most common GHGs are shown in Table 1.1.

**Table 1.1: GWP Values for Common GHGs (Reproduced with Permission from Brander, 2012)**

| Greenhouse Gas | | Global Warming Potential (GWP) |
|---|---|---|
| 1. | Carbon dioxide ($CO_2$) | 1 |
| 2. | Methane ($CH_4$) | 25 |
| 3. | Nitrous oxide($N_2O$) | 298 |
| 4. | Hydrofluorocarbons (HFCs) | 124 – 14,800 |
| 5. | Perfluorocarbons (PFCs) | 7,390 – 12,200 |
| 6. | Sulfur hexafluoride ($SF_6$) | 22,800 |
| 7. | Nitrogen trifluoride ($NF_3$)[3] | 17,200 |

As shown in Table 1.1, the GWP of $N_2O$ means that 1 ton of $N_2O$ can absorb 298 times more heat than $CO_2$; therefore, $N_2O$ is considered a more threatening GHG as compared to $CO_2$ in terms of global warming. The "carbon dioxide equivalent" unit (CO2e) uses the GWP index by multiplying the amount of a GHG is by its GWP, allowing for easy comparison between various GHGs (e.g., 1 ton of $N_2O$ is equal to 298 tons of CO2e). CO2e is helpful for comparing the total global warming potential of a package of GHGs relative to other packages (Brander, 2012). A package of GHGs refers to the group of multiple GHGs that get released during a process. For example, the package of emitted GHGs due to fossil-fueled electricity production consists primarily of $CO_2$, but also consists of smaller amounts of $CH_4$ and $N_2O$. This package is commonly quantified in CO2e. CO2e equalizes the properties of emissions, allowing easy comparison of possible reduction solutions.

Although CO2e is helpful for comparing and contrasting the effectiveness of different policies, the true scale of GHG reform based on CO2e is still difficult to quantify. For example, a seemingly simple GHG reduction of a fraction of a percentage point in overall emissions from a particular country can result in a reduction of several million tons of CO2e. Therefore, many reduction reform measures reference a GHG reduction amount in terms of tons of CO2e and simple percentages, allowing the general public to understand the impact of one ton of CO2e on a national or global scale. This paper utilizes both CO2e and percentages when describing specific policies and GHG reduction analyses.

## What is the United States' Role in GHG Reductions?

One pioneering worldwide GHG reduction initiatives is known as the Kyoto Protocol (KP). Negotiated in December 1997 and made effective in 2005, the KP is an agreement between37 industrialized countries committed to reducing collective emissions of GHGs (from 2008 to 2012) by 5.2% compared to 1990 levels (United Nations Framework Convention on Climate Change [UNFCCC], 2013). This unprecedented agreement between countries to reduce GHGs represents a significant initial step towards climate change reform. However, much work remains. The most recent study by the World Resources Institute (WRI) (2011) revealed the world's leading contributors to global GHG emissions, shown in Figure 1.1.

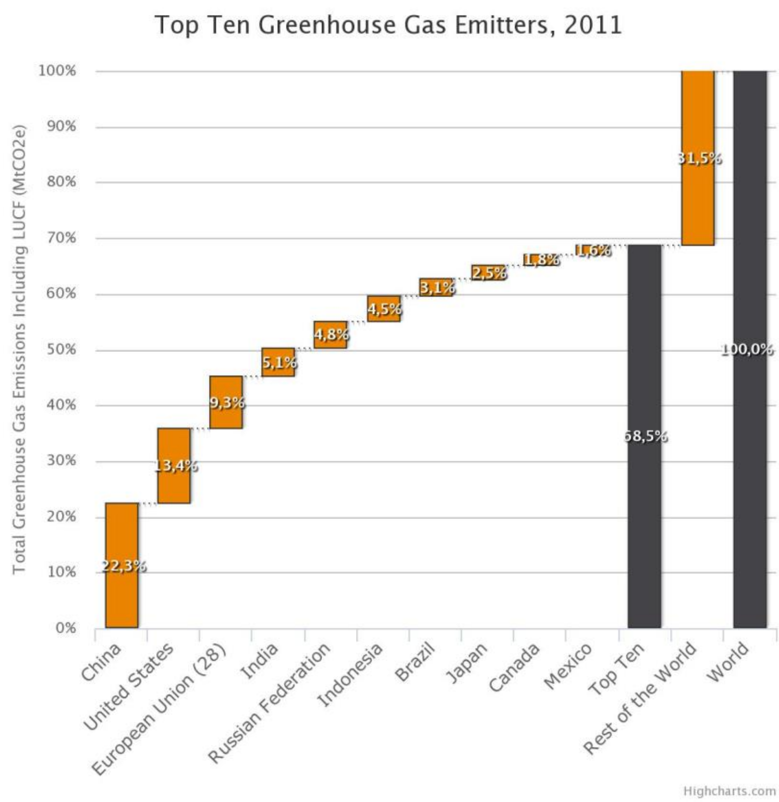



**Figure 1.1: Top Ten Greenhouse Gas Emitters in 2011 (Reproduced with Permission from Friedrich & Damassa, 2014)**

This figure shows that countries throughout the world are not meeting the goals set forth by the KP. In addition, the top ten emitters comprise 69% of total global GHG emissions, meaning that GHG reduction policy changes for those emitters will positively affect a majority of the world. At 13.4%, the U.S. is the second most significant contributor to GHG emissions, therefore the nation has a significant opportunity to affect climate change. The KP recognized this opportunity and required the U.S. to reduce GHGs by 7%, an increase from the overall reduction percentage of 5.2% (UNFCCC, 2013). According to the 1990 baseline of 5,402 million metric tons (MMT) of CO2e, the 7% reduction amounted to an average annual 378 MMT reduction from 2008 to2012 (UNFCCC, 2013). Although President Clinton signed the KP in 1997, the U.S. did not ratify the protocol in Congress and the agreement was not legally binding. Consequently, from the years 2008 to 2012, the U.S. had an annual average *increase* of 410 MMTCO2e, which is a 7.6% *increase* over the 1990 baseline (UNFCCC, 2013). In comparison, China's GHG emissions grew 339% over 20 years from 2,458 MMTCO2e in 1990 to 8,333 MMTCO2e in 2010 (British Petroleum [BP], 2011). Actions in both countries need to be taken to reduce growth rates of GHG emissions. Even though the growth rate of GHG emissions in the U.S. pales in comparison to China, because the U.S. is a leading contributor to global GHGs but has shown no signs of significant progress in GHG emissions reduction, national emission reduction goals must be established and met.

President Barack Obama has recognized the need to strengthen national GHG emission standards and has attempted to set the course for U.S. GHG reduction. One of the most recent and significant U.S. GHG reduction policies, set in 2009, calls for reducing GHGs 17% below 2005 levels by 2020, 26-28% by 2025, and 83% by 2050 (The White House [TWH], 2014). Since 2009, federal policies have been enacted across many industries to meet these goals:

- The Department of Energy (DOE) set goals of reducing pollution by 3 gigatons by 2030 using conservation standards for the building sector and for appliances and equipment (TWH, 2014).
- In May 2014, the Montreal Protocol, a proposal to phase out production of hydrofluorocarbons (HFCs) was submitted in partnership with Canada and Mexico. The proposal is estimated to reduce GHGs by 90 gigatons by 2050 (TWH, 2014).
- In August 2015, the EPA finalized strategies under the Clean Power Plan (CPP) that would reduce power sector emissions 32% below 2005 levels by utilizing state-by-state reduction requirements, a total reduction of 870 million tons (EPA, 2015, August).

Even with the above policies, however, the current state of energy efficiency in the U.S. is far below efficiency standards of other countries. A study known as the 2014 International Energy Efficiency Scorecard (IEES) ranked the U.S. well behind the world's other economically developed nations. Although the European Union (EU) is not a country, it was included in the 2014 IEES because "as a whole it represents an economy comparable to that of the United States in many ways" (Young et al., 2014). The 2014 IEES evaluated policy and performance metrics of every country. Young et al. (2014) defined the metrics in the following way:

> The policy metrics were scored based on the presence in a country or region of a best-practice policy. Examples of policy metrics include the presence of a national energy savings target, fuel economy standards for vehicles, and energy efficiency standards for appliances. The performance metrics are a measure of energy use and provide

quantifiable results. Examples of performance metrics include average miles per gallon of on-road passenger vehicles and energy consumed per square foot of floor space in residential buildings. The metrics are distributed across the three primary sectors responsible for energy consumption in an economically developed country: buildings, industry, and transportation.

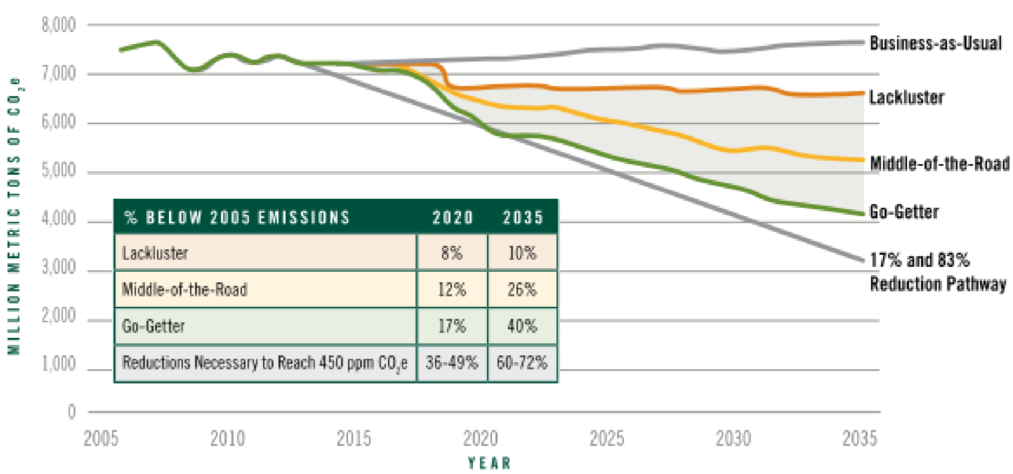
Using these metrics, the maximum score for a country is 100 points. The summary in Table 1.2 demonstrates the results of the study.

**Table 1.2: ACEEE 2014 International Energy Efficiency Scorecard Summary (Reproduced with Permission from Young et al., 2014)**

| | Total (100 points) | |
|---|---|---|
| | Score | Rank |
| Germany | 65 | 1 |
| Italy | 64 | 2 |
| EU | 63 | 3 |
| China | 61 | 4 |
| France | 61 | 4 |
| Japan | 57 | 6 |
| UK | 57 | 6 |
| Spain | 54 | 8 |
| Canada | 50 | 9 |
| Australia | 49 | 10 |
| India | 45 | 11 |
| South Korea | 44 | 12 |
| USA | 42 | 13 |
| Russia | 35 | 14 |
| Brazil | 30 | 15 |
| Mexico | 29 | 16 |

According to the results, the U.S. ranked 13 out of 16 countries with 42 points and only limited progress has been shown since the 2012 IEES. For comparison, Germany, the top ranked country, had an overall score of 65 points. Furthermore, the U.S. currently ranks below countries such as India and South Korea in terms of energy efficiency. Due to the reputation of the U.S. as "an innovative and competitive world leader", the results of this study are troubling (Young et al., 2014). One theory for the United States' decline in ranking asserts that smaller countries have economic advantage "because using less energy to produce and distribute the same economic output costs them less" (Young et al., 2014). Furthermore, this advantage compounds over time as investment in energy efficiency establishes increased long-term economic resiliency. If the decline in ranking continues, the U.S. no longer has to be concerned with being a leader in a global economy, but rather merely competing with other countries as the U.S. continues to "waste money and energy that other industrialized nations save and can reinvest" (Young et al., 2014).

In addition to declining on global energy efficiency rankings, the U.S. is failing to achieve national GHG emission reduction goals as well. A study from WRI concluded that without new policies set by the U.S. administration and subsequent actions by relative industries, the U.S. will fail to meet reduction goals outlined by President Obama in 2009 (Bianco, Litz, Meek, & Gasper, 2013). The WRI report included a variety of scenarios to outline actions required within all industries, including power, transportation, industrial, commercial and residential buildings, and agriculture, in order to get back on track with GHG emission reduction goals. The report distinguished federal and state actions in order to determine maximally effective combinations. In order to make generalizations about GHG emissions improvement across multiple industries, WRI has quantified measures of effort in action towards GHG reduction. Projections of U.S. emissions under various federal scenarios are shown in Figure 1.2.




| % BELOW 2005 EMISSIONS | 2020 | 2035 |
|---|---|---|
| Lackluster | 8% | 10% |
| Middle-of-the-Road | 12% | 26% |
| Go-Getter | 17% | 40% |
| Reductions Necessary to Reach 450 ppm $CO_2e$ | 36-49% | 60-72% |

**Figure 1.2: Projected U.S. Emissions under Various Federal Regulatory Scenarios (Reproduced with Permission from Bianco et al., 2013)**

The levels of effort refer to subjective terms defined by WRI. A Lackluster effort refers to actions of lowest cost and least optimistic technical achievement. The Middle-of-the-Road effort refers to actions of moderate cost and moderately optimistic technical achievement. The Go-Getter effort refers to higher cost and most optimistic technical achievement. However, by itself, a Go-Getter effort at a state or federal level will not help the country meet emission reduction goals. Therefore, this study proposes that the most cost-effective and realistic way to meet energy efficiency goals is to pursue emission reduction with Middle-of-the-Road federal action and a Go-Getter state effort (Bianco et al., 2013). Projections of U.S. emissions under this scenario are shown in Figure 1.3.

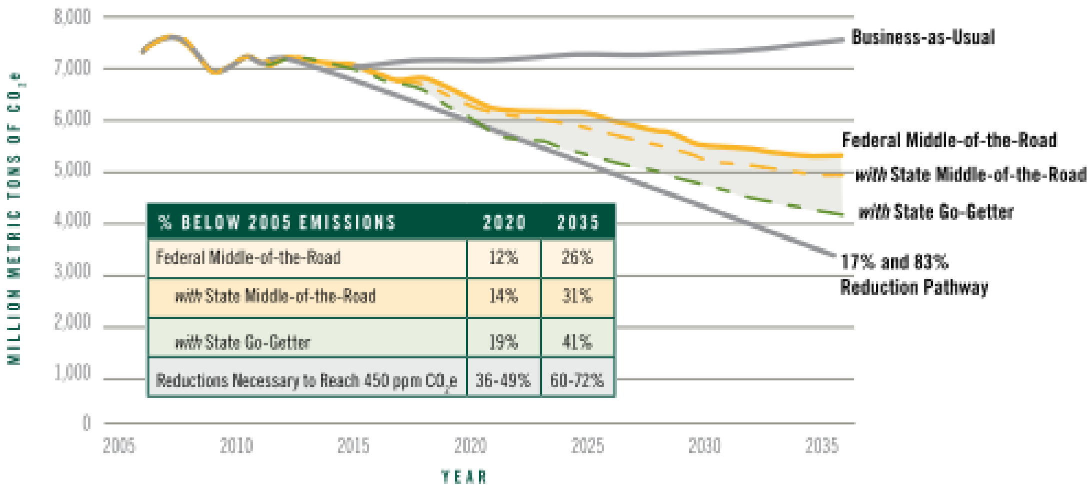



**Figure 1.3: Projected U.S. Emissions with State Action and Middle-of-the-Road Federal Action (Reproduced with Permission from Bianco et al., 2013)**

Even with Middle-of-the-Road federal action and a Go-Getter state effort, the 83% reduction by 2050 would not be met in the United States; however, the 17% reduction by 2020 would be met and would come as close to the goals as is currently feasible. All industries must take numerous actions in order to meet the WRI standards. Although actions dictated by the WRI are suggestions and not the only means for achieving reduction goals, the emphasis on improving state action for GHG reduction should be noted by policymakers. The key to attacking GHG reduction, according to WRI, is to first and foremost act on a state level (Bianco et al., 2013). Unfortunately, many barriers towards GHG emission reduction for industries are addressed on a national scale rather than at the state level. For example, in the transportation industry, vehicle mileage efficiency standards are set nationally and not by each state, and in the power sector, emission reductions are set by policies associated with the EPA. Although industries could take minor actions on the state level (reducing vehicle mileage through public transit or energy efficiency targets for power), there are arguably no industries in which state action is more powerful than the building industry.

## What is the Building Industry's Role in Reducing GHG Emissions?

Several reasons exist for why the building industry is one of the vital sectors to consider when advancing national GHG emission reduction efforts. The breakdown of GHG emissions in the U.S. by economic sector is shown in Figure 1.4. The total U.S. GHG emissions in million metric tons of CO2e (MMTCO2e) for 2013 was 6,638.

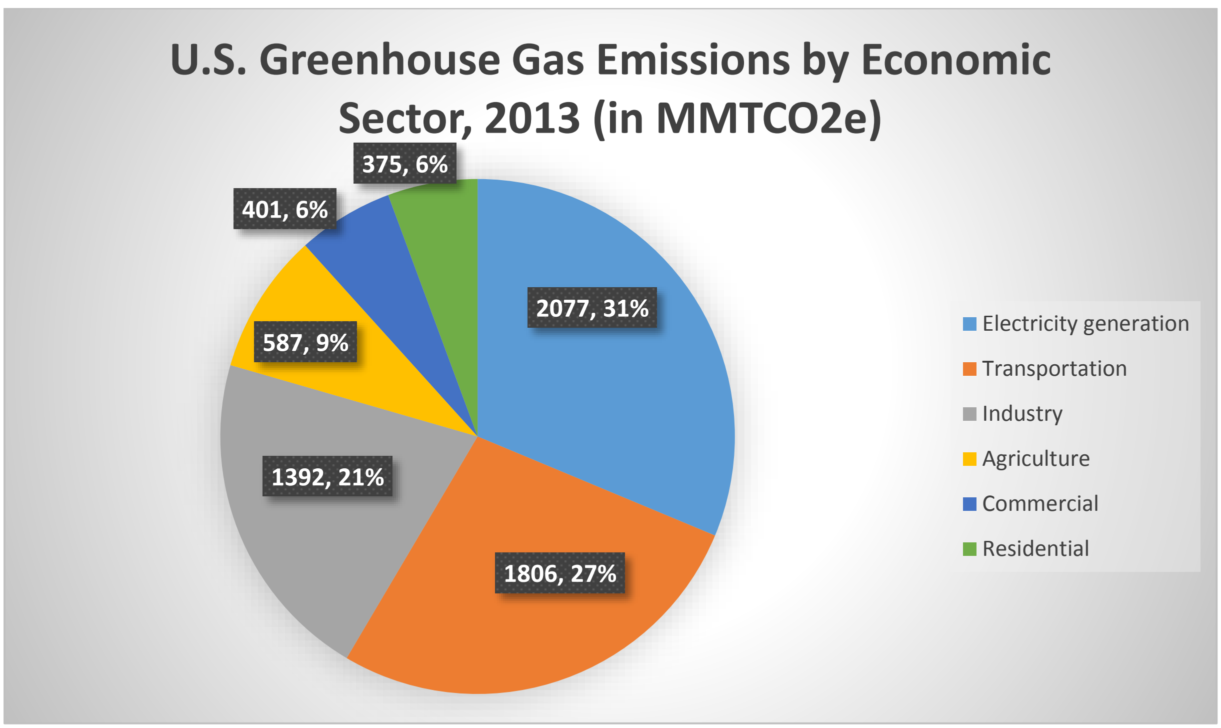



**Figure 1.4 : U.S. Greenhouse Gas Emissions by Economic Sector (Adapted with Permission from EPA, 2015, April)**

Electricity generation comprises the majority of GHG emissions in the U.S. at 31%, followed by transportation at 27%, and industry at 21%. Commercial and residential facilities only generate 12% of GHG emissions by themselves. However, this figure only accounts for *direct* emissions in the commercial and residential sector such as those resulting from fossil fuel combustion for cooking and heating processes, management of waste water, and leaks from refrigerants (EPA, 2015, April). When considering *indirect* emissions from the building sector, such as the emissions resulting from electricity consumption, the commercial and residential sector comprises 34% of electricity usage in the U.S. (a contribution equal to 706 MMTCO2e), so pushing for reform in the building industry can greatly influence the power industry (the largest contributor) (EPA, 2015, April). In addition, energy usage in the building industry is projected to increase; commercial building stock in the U.S. is set to increase 48% by 2030 (Creyts, Derkach, Nyquist, Ostrowski, & Stephenson, 2007). Failure to rapidly utilize the unrealized potential of energy savings across the industry will only escalate GHG emissions in the future.

Understanding the effect that hydrocarbon (oil, natural gas, and coal) fuel prices have on electricity production and GHG emissions is vital for GHG emission reduction in the building industry. Because the building industry depends significantly on the utility industry and the utility industry is reliant on fuel prices, changes in one industry logically affect the other. Oil prices in 2015 at approximately $47/barrel are the lowest they have been since the 2004 price of $45/barrel (Energy Information Administration [EIA], 2015). A graph of oil prices since 1996 is shown in Figure 1.5.

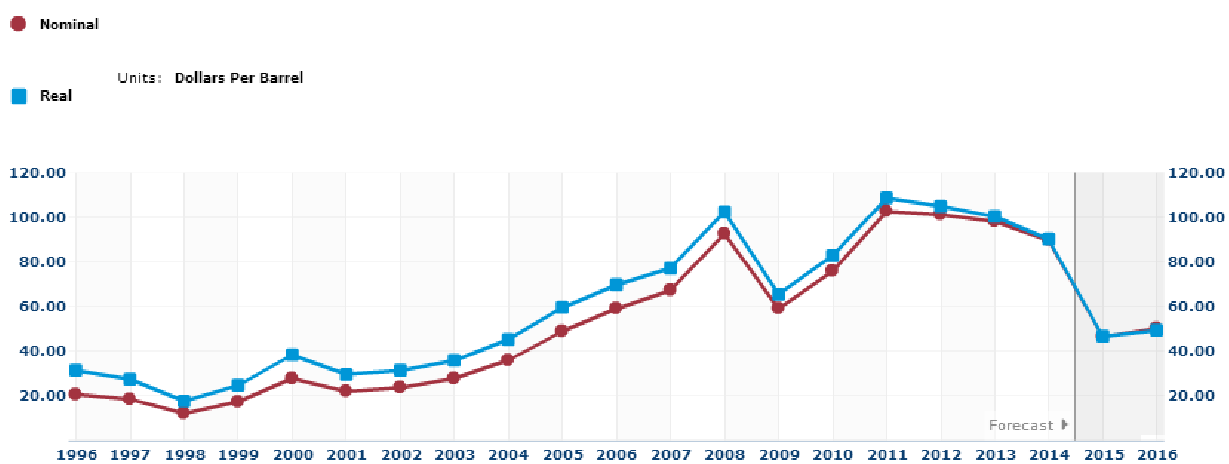



**Figure 1.5: Nominal and Real Crude Oil Retail Prices from 1996 to 2016 (Reproduced with Permission from EIA, 2015)**

Historically, oil prices have been directly related to coal and natural gas prices, meaning an increase in oil prices leads to an increase in coal and natural gas prices. Consequently, high hydrocarbon prices (occurring naturally or through a tax) stimulate investments into energy efficiency and renewable energy options, leading to diminished GHG emissions. However, low hydrocarbon prices lead to increased reliance on hydrocarbons for utility use and decreased motivation for investment into energy efficiency, resulting in rising GHG emissions. Analysis done by van Ruijven and van Vuuren (2009) assert that the price of coal is no longer linked to the price of other hydrocarbons because of coal's general price unpredictability and new resources to be brought under production. Therefore, without effective climate policy, high hydrocarbon prices will shift electricity production from natural gas-based power plants to coal-based power plants, resulting in a long-term increase in GHG emissions (van Ruijven & van Vuuren, 2009). On the other hand, low hydrocarbon prices lead to a business-as-usual scenario with GHG emissions due to minimal financial and budgetary pressure to invest in energy efficiency. Results of this analysis prove the importance of climate policy for the reduction of GHG emissions, since hydrocarbon prices alone can no longer steer the utility industry in the right direction.

Situations unrelated to hydrocarbon fuel prices are also currently affecting the utility industry. The electric utility industry is shifting into unfamiliar territory due to decline in sales. Historically, electricity sales have grown around 10% annually (Nadel & Herndon, 2014), but since the beginning of the twenty-first century, electricity sales have grown only approximately 1.5% per year (Nadel et al., 2014). Since 2007, electricity sales have been in the first multiyear decline in history (Nadel et al., 2014). One factor for this decline was the Great Recession in 2008 and 2009, but even with a growing U.S. economy, electricity sales have continued to decrease (Nadel et al., 2014). Concurrent to declining revenue, the infrastructure of transmission and distribution systems is aging and new investments are needed in order to maintain reliability and customer satisfaction, resulting in increasing electricity rates. Given the rise and feasibility of renewable technology, increasing numbers end-users will be forgoing consumption of electricity from the grid in favor of on-site renewables, resulting in what the industry is projecting to be a "death spiral" in which fewer customers are left to pay for the cost of the grid (Nadel et al., 2014). Because of the threat of this death spiral, the electric utility industry is motivated to invest in energy efficiency in order to minimize the required reinvestment in infrastructure.

The natural gas environment is also experiencing changes. New extraction techniques, such as fracking ("a drilling technology that uses a mix of chemicals to dislodge natural gas from deep shale or coalbed methane deposits"), are increasing the supply of natural gas and thus decreasing natural gas prices (Davis, 2012). Identical to the electric industry, natural gas utilities are also desiring to invest in energy efficiency. One of the most cost-effective means of energy efficiency is the up-front investment in energy-efficient design practices. Fortunately for the utility industry, a well-known and tested vehicle for efficient design practice already exists in building energy codes.

# Chapter 2 - The Current State of Building Energy Codes

The DOE founded the Building Energy Codes Program (BECP) in 1992 in response to the Energy Policy Act (EPAct) of 1992, "which mandated that DOE participate in the model national codes development process and help states adopt and implement more efficient energy codes" (Livingston et al., 2014). Through the BECP, the DOE participates in the development of codes and standards maintained by the International Code Council (ICC), the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and the Illuminating Engineering Society (IES). In addition to code development, the DOE provides assistance for the code adoption process on a state and local level and is available to provide a variety of technical support. The BECP has been considered a success, with a ratio of $400 of cost savings for each dollar the DOE has spent on the BECP (Livingston et al., 2014). Given the historical precedent and success exemplified by the BECP, increased adoption and compliance with building energy codes may be the easiest, fastest, and most effective ways to achieve some GHG reductions, even if building energy codes by themselves will not enable the U.S. to meet WRI recommendations.

## History of Building Energy Codes

Prior to 1970, building design and construction energy usage was not regulated due to an abundance of oil, gas, and electricity supplies that subsequently led to low energy prices. With low prices and abundant supplies, there was no need to regulate how much energy buildings were using. The turning point in the history of energy regulation was the oil embargo in 1973, instituted by the Organization of Petroleum Exporting Countries (OPEC). Because of this embargo, energy costs rose and decreased energy usage became a priority for consumers, building owners, and the U.S. government. In 1975, ASHRAE responded to rising energy prices and need for decreased energy usage by proposing their first energy standard: Standard 90-75 Energy Conservation in New Building Design (Hunn, 2010). This standard was the first document that regulated lighting and building envelope designs for energy conservation.

As expected, adoption of this new standard was initially slow, partly due to the language of the standard. Instead of enforceable code language, the wording of the standard focused more on design rather than compliance. Therefore, the Model Energy Code (MEC) was published in 1983 as a method for states to adopt the concepts of the ASHRAE energy standards (Hunn, 2010). As a result, by the mid-1980s more than half the states had adopted energy provisions for buildings (Hunn, 2010). Although half of states had adopted provisions, no requirements existed until the EPAct of 1992. This act stated that "all states must adopt energy codes for commercial building codes at least as stringent as ASHRAE Standard 90.1" (Hunn, 2010). Even though this act had "no real enforcement mechanism", the possibility of federal funds was available providing that states met or exceeded the energy levels required by the act (Hunn, 2010). The incentive of funding, as well as the motivation of energy savings within state-owned buildings themselves, prompted renewed interest in energy standards from the states and subsequently the building industry (Hunn, 2010). In 1998, the MEC was replaced with the International Energy Conservation Code (IECC), and the two model codes for states to implement became the IECC and ANSI/ASHRAE/IES Standard 90.1 (Hunn, 2010). Since 2000, the IECC has been updated every three years. Likewise, since 2001, ANSI/ASHRAE/IES Standard 90.1 has been updated every three years. The most recently published versions of each, respectively, are the 2015 IECC and ANSI/ASHRAE/IES 90.1-2013. In recent years, "above-code" standards have become more commonplace. ANSI/ASHRAE/IES has teamed up with the United States Green Building Council (USGBC) to issue ANSI/ASHRAE/USGBC/IES Standard 189.1 which references ANSI/ASHRAE/IES Standard 90.1, but sets higher standards. Likewise, an alternative to the IECC, the International Green Construction Code (IGCC), has also been published. The most recently published versions of each are ANSI/ASHRAE/USGBC/IES Standard 189.1-2014 and the 2015 IGCC. In addition to these standards, states and local jurisdictions can also create and adopt their own energy standards, often referred to as "stretch codes". Notable examples include Title 24 in California, the Washington State Energy Code, and the Massachusetts Stretch Code (Denniston, Dunn, Antonoff & DiNola). Because of the relatively new creation and low adoption of these "above-code" standards, this paper will focus on the IECC and ANSI/ASHRAE/IES

Standard 90.1 (commonly referred to as ASHRAE Standard 90.1). In addition, focusing on the IECC and Standard 90.1 allows analysis over multiple climate zones and states, as opposed to if state or jurisdiction-specific stretch codes.

## Process of Building Energy Code Adoption

Because the United States does not have a national building energy code requirement, energy code compliance is decided at a state or local level. This local level adoption is in contrast to other countries and entities, such as Germany, Italy, and the EU, which all have mandatory national building energy code requirements and respectively comprise the top three rankings of the 2014 International Energy Efficiency Scorecard (Young et al., 2014). Although the scorecard ranks many industries in addition to the building industry, out of the 16 countries ranked in the scorecard, seven do not have mandatory requirements and five of those seven countries are in the bottom half of the scorecard (Young et al., 2014). Since compliance in the U.S. is voluntarily decided, most states adopt energy codes through direct legislative action or through regulatory action by an advisory body appointed by local authorities (DOE, 2010). It should be noted that even if a code is adopted at a state level, it is not necessarily adopted at a local level. Figure 2.1 shows the steps in a typical government's (state or local) energy code adoption process.

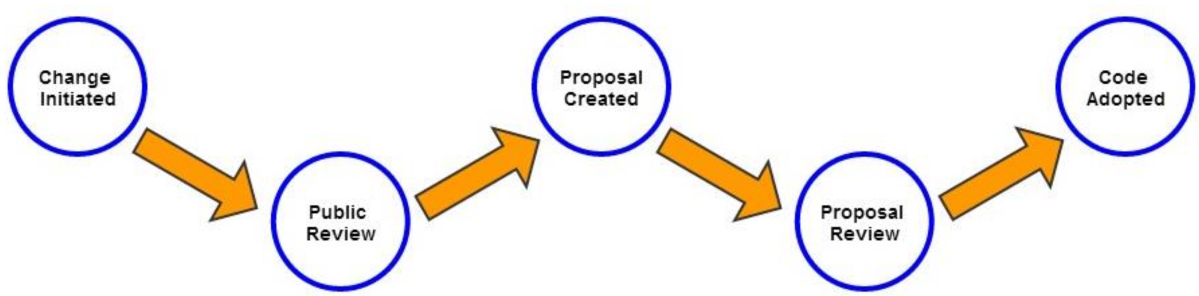



**Figure 2.1: Steps of an Energy Code Adoption Process by State or Local Government (Adapted with Permission from DOE, 2010)**

As shown in Figure 2.1, the **code adoption process** has five basic steps:

- A **change is initiated** to state or local legislature due to a desire to take advantage of a new energy code. An advisory body appointed by local authorities recommends either a different energy code or an addendum to an existing model code.

- A **public review** process takes place to review considered changes. The advisory body can call upon any interested or affected parties to bring their expertise to the process. These interested parties can include building engineers, contractors, or architects.
- A **proposal is created** that encompasses results of the review process and the proposal is then officially submitted to the designated authority for approval.
- The **proposal is reviewed** by the authority having jurisdiction. Revisions may be suggested during this process and those revisions will also be reviewed for approval.
- After being approved, the **code is adopted** either effective immediately or on an agreed-upon future date. A grace period is typically established to allow the parties affected to become familiar with the new changes. This period can vary from 30 days to 6 months.

Although the IECC and ASHRAE Standard 90.1 are considered equivalent codes, most states adopt versions of the IECC rather than ASHRAE Standard 90.1 primarily "because the IECC is a model code and part of a coordinated set of model building codes that state and local government have historically adopted" (Makela, Williamson, & Makela, 2011). Another reason for more common adoption of the IECC is that the IECC references commercial construction and low-rise residential construction, whereas ASHRAE Standard 90.1 excludes low-rise residential construction. Although the IECC is more widely adopted, engineers prefer to utilize ASHRAE Standard 90.1 for code compliance, mostly due to historical precedence of commercial construction design. This use of ASHRAE Standard 90.1 is usually not an issue in jurisdictions that have adopted the IECC, since the methods of compliance for the 2015 IECC is to comply with ASHRAE Standard 90.1-2013, according to Section C401.2 of the 2015 IECC (ICC, 2014). Both of these codes have been developed and continuously revised in public forums comprised of various experts in the building industry.

## Issues and Benefits of Building Energy Codes

As evidenced in the history, background, and adoption procedure of building energy codes, benefits and problems exist for the full utilization of codes throughout the United States. Obvious benefits include decreased energy consumption and lower utility bills. Other less-obvious benefits include increased employment rates and economic stimulation. The same pattern of obvious and less-obvious appears with the problems as well. The convoluted process of adoption is a clear disadvantage to widespread adoption and compliance, as are the methods of enforcement. One of the lesser known concerns is a lack of awareness of the energy cost savings to owners of buildings adhering to energy codes. A perception exists that in order for energy savings to occur, a premium must be paid. The overall first cost usually increases by adhering to energy codes, but national research results have shown that every dollar invested in increasing compliance to codes leads to $6 in energy savings (Stellberg, 2013). All major benefits and issues are summarized and discussed in the following sections in order to clearly describe the current state of energy codes.

## *Issues of Building Energy Codes*

Of the many current problems and issues with current building energy codes, five of the most significant and relevant are highlighted in the following sections.

### *First Cost*

A general perception exists that the first cost of building energy code compliance is often too high to make financial sense, regardless of the savings acquired over the life of the building. Although life cycle cost analyses have proven that the added first cost almost always pays back over the life of the building, building owners often are not sufficiently convinced to implement energy efficient designs since dollars up front seem to matter more than dollars in the future. The Pacific Northwest National Laboratory (PNNL) and ASHRAE have conducted cost-effectiveness analyses of recent ASHRAE standards in order to study how first cost and energy savings relate over the life of an average building. A comparison of total building cost and incremental first cost for adoption of the most recent standard (90.1-2013) to the oldest standard with available cost data (90.1-2007) is shown in Table 2.1. This data is for new construction only and does not account for remodel construction.

**Table 2.1: First-Cost Difference between ASHRAE Standard 90.1-2013 and ASHRAE Standard 90.1-2007 (Adapted with Permission from Hart et al., 2015 and Thornton et al., 2013)**

| Incremental First-Cost Difference Between ASHRAE Standard 90.1-2013 and ASHRAE Standard 90.1-2007 | | | | | | |
|---|---|---|---|---|---|---|
| Prototype Building | Value of Prototype Building ($/ft$^2$) | ASHRAE Climate Zone Type | | | | |
| | | 2a | 3a | 3b | 4a | 5a |
| | | Houston | Memphis | El Paso | Baltimore | Chicago |
| | | $/ft$^2$ | $/ft$^2$ | $/ft$^2$ | $/ft$^2$ | $/ft$^2$ |
| Small Office | $ 128.50 | $ 1.46 | $ 1.43 | $ 1.55 | $ 5.02 | $ 3.22 |
| | | 1.14% | 1.11% | 1.21% | 3.91% | 2.51% |
| Large Office | $ 162.00 | $ 1.61 | $ -1.10 | $ -2.06 | $ 1.19 | $ -1.54 |
| | | 0.99% | -0.68% | -1.27% | 0.73% | -0.95% |
| Standalone Retail | $ 89.00 | $ 0.64 | $ 1.09 | $ 0.15 | $ 2.42 | $ 1.61 |
| | | 0.72% | 1.22% | 0.17% | 2.72% | 1.81% |
| Primary School | $ 135.00 | $ 3.01 | $ 3.64 | $ 0.34 | $ 4.29 | $ 3.86 |
| | | 2.23% | 2.70% | 0.25% | 3.18% | 2.86% |
| Small Hotel | $ 108.50 | $ 0.58 | $ 0.31 | $ 0.41 | $ 0.90 | $ 0.71 |
| | | 0.53% | 0.29% | 0.38% | 0.83% | 0.65% |
| Mid-rise Apartment | $ 114.00 | $ 0.79 | $ 1.31 | $ 1.31 | $ 1.00 | $ 1.20 |
| | | 0.69% | 1.15% | 1.15% | 0.88% | 1.05% |

Additional first costs associated with adherence to the current energy standard never exceeds 4% of the total building cost, sometimes reducing first cost altogether. Regardless of long-term cost-effectiveness building energy codes, implementation of energy efficient measures is more expensive than non-implementation, causing one of the most significant obstacles for building owners. A survey done by the Johnson Controls Institute for Building Efficiency (JCIBE, 2013, June), encompassing “over 3000 global executives with decision-making authority over their company and organization’s energy investments and activities,” showed that lack of capital availability is the primary deterrent to energy efficiency worldwide. In the U.S. and Canada specifically, a resounding 31% of the 600 participants in the study stated that available funding was the main barrier (JCIBE, 2013, June). JCIBE (2013, June) also asked participants: “which of the following energy policies would have the greatest impact on improving energy efficiency in buildings?” Responses to this question are shown in Figure 2.2.

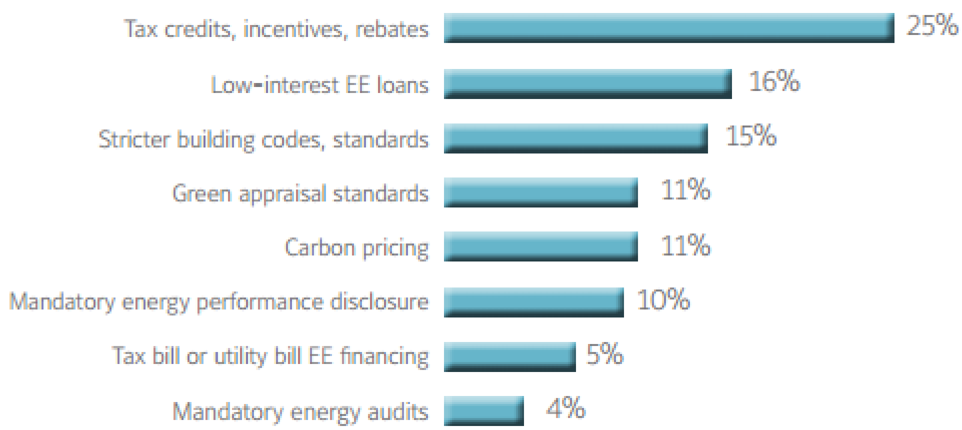



**Figure 2.2: Results of Survey for Global Executives on Methods to Improve Energy Efficiency Economics (Reproduced from JCIBE, 2013, June)**

Although tax credits, incentives, and rebates were predictably the most popular responses, stricter building codes and standards ranked in the top 3 responses. Beyond the issue of financing, global executives agree that the best policy for increasing the number of energy efficiency initiatives involves stricter building codes and standards.

***Lack of Public Belief***

Within the national discussion of GHG emissions, and in the WRI study done by WRI previously described in Chapter 1, a general lack of public awareness exists regarding the potential energy savings from adherence to building energy codes. The study stated that a focus on power plants for GHG reduction savings are the highest priority because they represent over 30% of the national GHG emissions (Bianco et al., 2013). Since buildings consume 72% of electricity usage in the U.S, concentrated focus on energy efficiency in the building industry could significantly decrease power plant GHG emissions and subsequently national GHG emissions (Livingston et al., 2014).

One of the biggest issues with belief in building energy code impact is the rise of beyond-code programs such as Leadership in Energy and Environmental Design (LEED) created by the United States Green Building Council (USGBC). Although LEED promotes construction and operational sustainability in buildings, the long-term effect LEED has on energy consumption has been questioned in recent years. Newsham, Mancini, and Birt (2009) found that "on average, LEED buildings used 18-39% less energy per floor area than their conventional counterparts. However, 28-35% of LEED buildings used more energy than their conventional counterparts."

Apart from these controversies, beyond-code programs can incentivize better-designed buildings, potentially resulting in lower operating costs for owners. Beyond-code programs can also allow for positive marketing opportunities and create real estate benefits since LEED buildings "commanded a 9.2% higher rent, and a 31% higher sale price" (Newsham et al., 2009). However, the up-front cost of LEED certification, which ranges from 0 to 3% more than total building cost, may discourage many owners from undertaking the process (Katz, 2008). In addition to the first cost associated with enhanced design, additional project costs are required for documentation and administrative costs that USGBC retains for the certification process. If the building is classified in the 28-35% of underperforming buildings, operating savings and real estate value could also be sacrificed. Instead of an expensive program, such as LEED, that awards outliers, a commitment to lowering the overall energy usage baseline may be more effective. If states committed to more quickly adopting current energy codes (assuming the majority of local jurisdictions follow the state's adoption patterns), average energy usage by state would decrease without added design and construction costs associated with LEED certification.

***Inadequate Enforcement***

One of the largest issues with building energy codes is the problem of inadequate enforcement. Inadequate enforcement results from many different factors, but arguably the most troublesome factors are tiered adoption patterns, complication with showing compliance, and a lack of training in new codes. As detailed in previous sections, the process of energy code adoption can be convoluted and time-consuming. Although energy standards are generally adopted at a state level, each jurisdiction, whether a city or county, has the choice to adopt or reject the standards chosen by the state. In each jurisdiction, "adoption of energy codes can occur directly though legislative action or by regulatory action through agencies authorized by the legislative body to oversee the development and adoption of codes" (DOE, 2010). Typically, financial motivators encourage adoption, but there is no penalty is imposed if adoption is rejected. As a result, jurisdictions often voluntarily adopt the same code. The same situation occurs between the state and federal levels. The DOE can recommend and financially motivate states to adopt a certain standard, but it is up to the state to decide whether they will adopt the standard or not. This lack of obligation is one of the many factors that lengthens the adoption process. In addition to the lengthy adoption process, the tiered levels of adoption can lead to difficulties with enforcement. Since different energy codes can be adopted for buildings at the federal, state, and local levels depending on the project, many levels of enforcement will be required for construction within a typical jurisdiction. Due to a lack of resources, states generally only enforce the state-adopted energy code for state-owned buildings. States usually do this through a designated agency which employs field inspectors (BECP, 2014). Local jurisdictions are then left to enforce the locally adopted code for the rest of the buildings within their area. Some states provide financial and personnel assistance to the local jurisdictions to help with enforcement, but this assistance does not always occur. Similarly, various enforcement responsibilities exist between the state and federal levels. This tiered adoption pattern can lead to confusion in enforcement. For example, in Manhattan, Kansas, a federally-owned building (the National Bio and Agro-Defense Facility), state-owned buildings (Kansas State University), and local buildings (any other commercial facility) all exist within blocks of each other. A diagram detailing this confusion is shown in Figure 2.3.

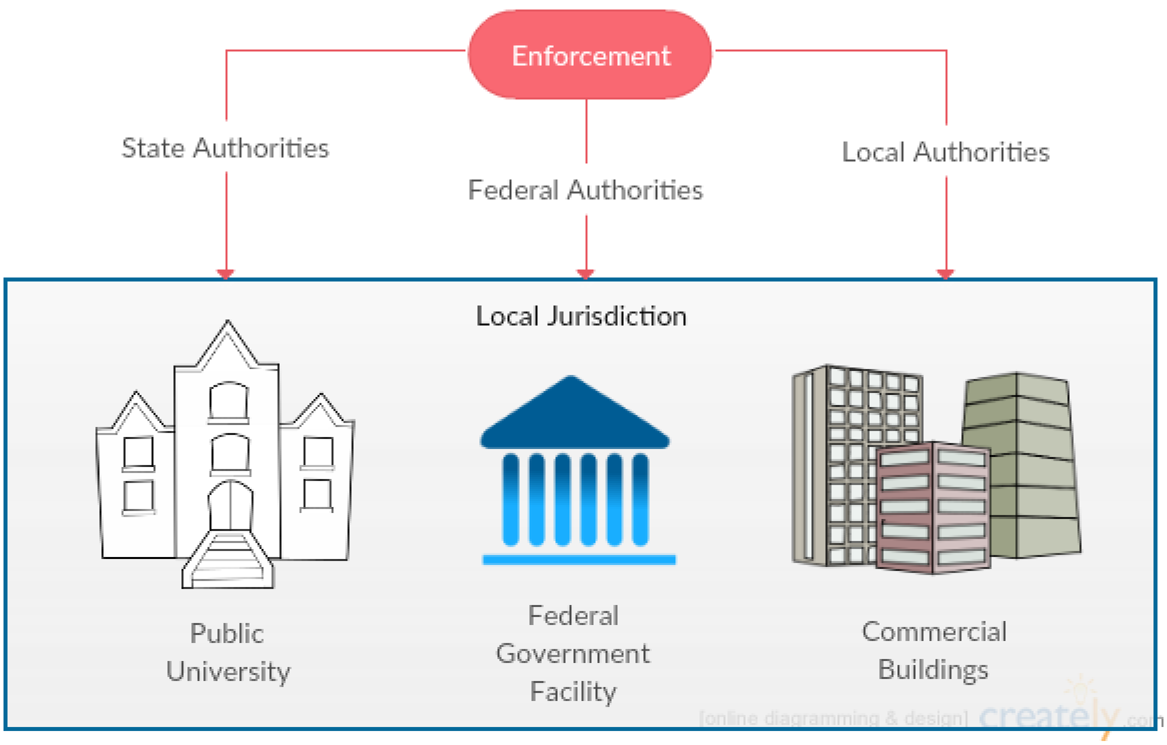



**Figure 2.3: Overlap with Enforcement Authority**

Since enforcing agencies will typically be responsible for multiple building codes, such as electrical, mechanical, fire, life safety, and energy codes, resources are often spread thin. Even though energy codes have been around for decades now, they are still relatively new to the building industry in terms of enforcement, especially compared to fire and life safety codes. As a result, methods of showing and checking compliance are not as standardized for building energy codes. There is no single way to determine compliance, but rather several commonly used methods. These include a pass-fail/ trade-off method utilizing software provided by the DOE, a method utilizing PNNL-BECP checklists, and building energy model simulations (Stellberg, 2013). As a result, compliance with building energy codes, even when they are adopted, is difficult to determine. When Stellberg (2013) attempted to measure current compliance, the rates were so sporadic and documentation was so irregular that she determined an insufficient amount of data was available to establish compliance rates by state. Instead, she determined that a low baseline compliance would be 25% and a high baseline compliance would be 75% (Stellberg, 2013). Although this study is not saying that 100% compliance is unachievable, a "high" compliance of only 75% is significant. In an industry where anything other than 100% compliance with fire and life safety codes is unacceptable, it is clear that energy codes are not as heavily prioritized.

Another obstacle to compliance is due to a lack of training in newly adopted codes resulting from time lag and high cost. Since local and state code officials are not involved in development of energy codes, the BECP (run by the DOE) is typically responsible for training local and state jurisdictions, including both development of training materials and leading training classes. Time spent for development of training materials and the complexity of training depend on the extent of the changes made between code versions. Ideally, the enforcement training process within a jurisdiction begins months in advance of a code change. However, this lengthy time requirement causes local jurisdictions to be more hesitant to adopt the new code until adequate training material is available. In addition to time lag, cost of training is also a factor in low energy code enforcement. Halverson et al. (2014) estimated that $34.3 million may be required for the estimated 40,000 jurisdictions to receive basic training for older versions of Standard 90.1, assuming one 8-hour day per jurisdiction. This total increases to $68.7 million when evaluating training for the most recent code (90.1-2013), assuming two 8-hour days per jurisdiction. Rather than leave training up to the BECP, another option would be to incentivize the organizations that develop codes, such as the ICC and ASHRAE, to be responsible for training. While this may help make materials more readily available to state and local jurisdictions, finding funding for training is often difficult. Since the federal government allocates money to the BECP for training, training should logically occur through the BECP. However, a compromise should be reached between the code organizations and the BECP to standardize and optimize training in order to reduce cost and time as much as possible. Multiple levels of adoption, difficulty with showing compliance, and hindrances to training are some of the primary reasons why building energy code enforcement is problematic.

### *Low Priority*

A further complication noted by a roundtable discussion of representatives "from local and federal governments, the private sector, and non-government organizations" orchestrated by Johnson Controls was relative lack of priority that investment in energy efficiency receives compared to other investments (JCIBE, 2013, July). For example, 28% of participants stated that the largest financial barrier to energy efficiency was insufficient capital, but another 32% stated that the largest financial barrier was actually competition for other investments (JCIBE, 2013, July). Results of this discussion are shown in Figure 2.4.

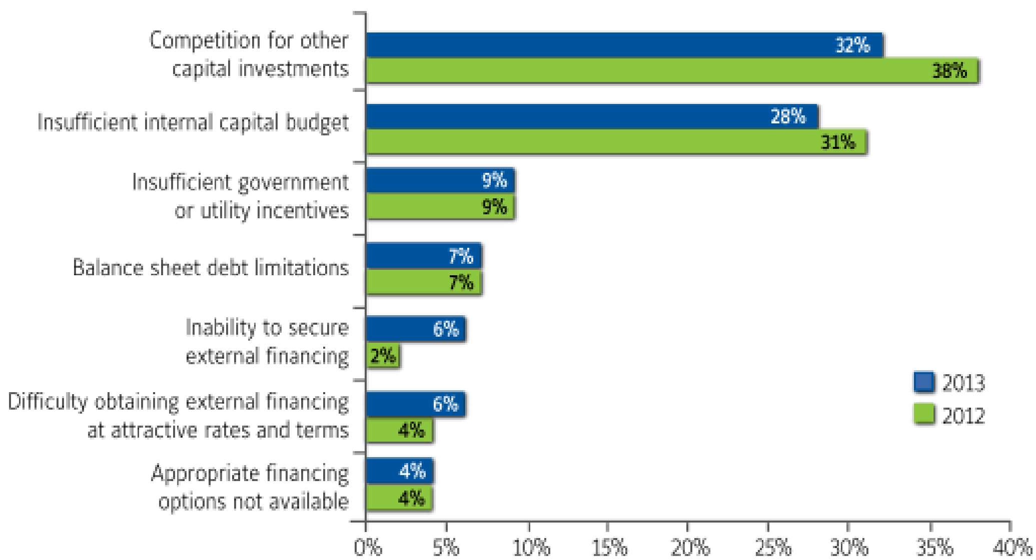



**Figure 2.4: Survey Results for Financial Barriers to Energy Efficiency (Reproduced from JCIBE, 2013, July)**

These results prove that even when return on investment is high and capital is available, investments in energy efficiency still rank lower than other capital investments in facilities such as aesthetic features. Possible solutions to this issue of low priority discussed within the group ranged from developing "energy plans" similar to business plans and revising government policies to drive changes in efficiency (JCIBE, 2013, July). Using revision of government policies as a solution to low priority implies that an increase adoption of current building energy codes could motivate positive changes in energy efficiency by increasing the priority of energy efficiency investments. An additional benefit of energy plan development could be inclusion on financial sustainability indices, such as the Dow Jones Sustainability Index (DJSI). The purpose of financial sustainability indices is to allow investors to see which firms are adopting sustainable strategies, since firms invested in sustainability are expected to outperform their counterparts over time (Lopez, Garcia, & Rodriguez, 2007). Ideally, inclusion on these indices would differentiate the sustainable firms from the unsustainable firms leading to a competitive advantage in the capital market (Lopez et al., 2007). Lopez et al. (2007) showed that over a short time frame (three years) no evidence exists that investment in sustainability practices provides a positive impact on performance. Regardless of the short-term effects, the fact that sustainability indices exist shows that investors may still be interested in firms' sustainability practices for long-term purposes. The sample DJSI questionnaire provided by RobecoSAM (2015) refers to a firm's environmental policy/management system, and although the existence of a system does not guarantee inclusion on the DJSI, it could be a significant factor in the selection process for the DJSI.

### *Lack of Adequate Funding*

Because building energy codes are adopted by states, the federal government is attempting to decrease GHG emissions by incentivizing the adoption of state codes. Currently, the amount of money allocated for code adoption to each state is determined by a formula that distributes one-third of total funding evenly across all states; the other two-thirds of funding is distributed based on state energy consumption and state population (Gilbraith, Azevedo, & Jaramillo, 2014). The total of this funding is currently $26 million annually. In a study done by Gilbraith et al. (2014), the overall private and social benefits of adopting building codes was determined to far exceed the funding currently being distributed to states. Private benefits refer to the monetary value of energy savings, and social benefits refer to monetized values associated with reductions in pollution (Gilbraith et al., 2014). Not only do the benefits of adoption of building energy codes exceed the funding, but they are also disproportionately issued by state based on social benefits, implying an error within the equation used by the government for allocation. A more equitable funding procedure would lead to a higher rate of code adoption and consequently lower GHG emissions throughout the United States. An example of how to improve the funding procedure is presented in Chapter 4.

### *Benefits of Building Energy Codes*

Now that the problems with building energy codes and their adoption have been outlined, the many benefits of building energy codes and their timely adoption are discussed in the following sections.

#### *Energy Savings Potential*

Although unrealized energy savings potential is available for the buildings complying with national building energy codes, the BECP has a proven record of historical savings. A study performed by Livingston et al. (2014) estimated that since BECP's inception in 1992 until 2012, a cumulative amount of 2.0 quads ($10^{15}$ BTU) of site energy and 4.0 quads of source energy has been saved, equating to an emissions savings of 335 MMTCO2e. Projections into the year 2040 suggest that an additional 22.0 quads of site energy and 44.1 quads of source energy are available to be saved, equating to an additional emissions savings of 3.5 billion MTCO2e (Livingston et al., 2014). To put this into perspective, 44.1 quads of energy is an entire year's worth of primary energy consumption in U.S. residential and commercial sectors (Livingston et al., 2014). The total of almost 3.9 billion MTCO2e savings is "equivalent to three-quarters of all energy-related emissions of the United States in 2012" (Livingston et al., 2014). An illustration of this amount of emissions from various industries is shown in Figure 2.5.

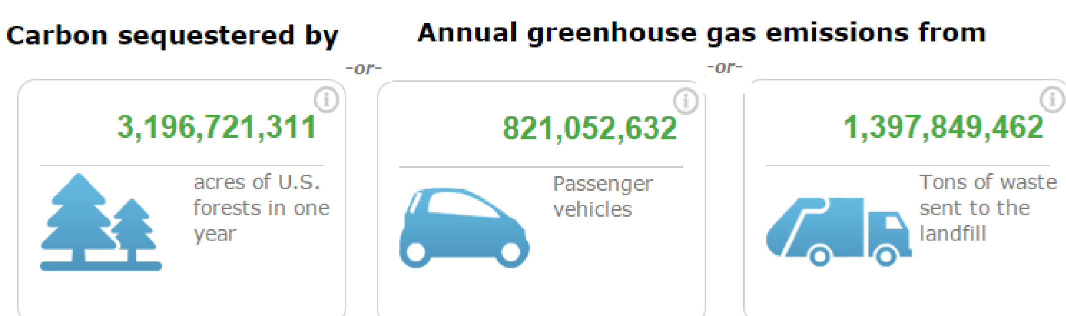



**Figure 2.5: Greenhouse Gas Equivalency Data for 3.9 Billion MTCO2e (Reproduced with Permission from EPA, 2015, September)**

In addition, these energy and emissions savings are projected with consideration of less than ideal compliance and adoption rates. A summary of these compliance and adoption rates is presented in Appendix A - With ideal adoption and compliance circumstances, the emissions savings could potentially be increased to 6.2 billion metric tons of $CO_2e$ (Livingston et al., 2014). The BECP has also achieved this savings cost-effectively, with a cost-to-savings ratio of 400:1 (Livingston et al., 2014). Further study of energy savings potential of increasing energy code adoption and compliance is detailed in Chapter 3.

***Relative Cost-Effectiveness***

Because ASHRAE Standard 90.1 is a model energy code, cost-effectiveness is essential to ensure increased adoption rates. During development of new versions of 90.1, "the cost-effectiveness of individual changes (addenda) is often calculated to support the deliberations of Standard Standing Project Committee (SSPC) 90.1" (Hart, Loper, Richman, Athalye, & Rosenberg, 2015). However, this method of cost analysis is often not applied to the entire set of addenda between standards. Therefore, PNNL conducted cost analyses of the latest 90.1 standards, including Standard 90.1-2007, Standard 90.1-2010, and Standard 90.1-2013. Due to the limited amount of resources available to complete the study, cost analyses were not performed for all prototype buildings across all climate zones. However, the selected prototype buildings captured almost all addenda between revisions of standards, included nearly all HVAC systems simulated in all models, and represented between 75% and 80% of floor area covered by all prototype buildings (Hart et al., 2015). The analyses, therefore, "provide a good representation of the overall code cost effectiveness, without requiring simulation of all 16" (Hart et al., 2015). A summary of the cost-effectiveness analysis for ASHRAE Standard 90.1-2013 as compared to ASHRAE Standard 90.1-2010 is shown in Figure 2.6.

| Prototype | | Climate Zone and Location | | | | |
|---|---|---|---|---|---|---|
| | | 2A Houston | 3A Memphis | 3B El Paso | 4A Baltimore | 5A Chicago |
| Life Cycle Cost Net Savings | | | | | | |
| Small Office | Total | $21,600 | $15,200 | $10,800 | $2,900 | $5,000 |
| | $/ft$^2$ | $3.93 | $2.76 | $1.96 | $0.53 | $0.91 |
| Large Office | Total | $740,000 | $1,650,000 | $2,540,000 | $300,000 | $1,340,000 |
| | $/ft$^2$ | $1.48 | $3.31 | $5.09 | $0.60 | $2.69 |
| Standalone Retail | Total | $84,000 | $81,400 | $53,800 | $67,000 | $79,000 |
| | $/ft$^2$ | $3.40 | $3.30 | $2.18 | $2.71 | $3.20 |
| Primary School | Total | $246,000 | $116,000 | $398,000 | $70,000 | $54,000 |
| | $/ft$^2$ | $3.33 | $1.57 | $5.38 | $0.95 | $0.73 |
| Small Hotel | Total | $96,410 | $76,000 | $78,000 | $62,600 | $57,000 |
| | $/ft$^2$ | $2.23 | $1.76 | $1.81 | $1.45 | $1.32 |
| Mid-rise Apartment | Total | $59,600 | $22,600 | $23,800 | $29,200 | $28,500 |
| | $/ft$^2$ | $1.77 | $0.67 | $0.71 | $0.87 | $0.84 |
| Simple Payback (years) | | | | | | |
| Small Office | | Immediate | Immediate | Immediate | 22.0 | 17.0 |
| Large Office | | 6.8 | Immediate | Immediate | 5.1 | Immediate |
| Standalone Retail | | Immediate | Immediate | Immediate | Immediate | Immediate |
| Primary School | | 5.5 | 9.5 | 0.6 | 14.3 | 15.6 |
| Small Hotel | | 3.9 | 4.1 | 4.0 | 7.2 | 8.7 |
| Mid-rise Apartment | | 1.9 | 11.7 | 11.4 | 7.2 | 9.7 |

**Figure 2.6: Summary of Cost-Effectiveness Analysis for ASHRAE Standard 90.1-2013 (Reproduced with Permission from Hart et al., 2015)**

As shown in the summary, all buildings across all climate zones exhibited a net savings resulting from adherence to ASHRAE Standard 90.1-2013. More notably is the simple payback section that shows a payback within the 30-year life of the building. Standalone retail showed an immediate payback in all climate zones, and small offices and large offices had immediate paybacks in three of the five climate zones selected. A majority of the other paybacks (21 out of 30) were less than or equal to a time period of five to seven years, which is a commonly referenced benchmark across the industry.

The payback analyses demonstrated that although a higher first cost is associated with adherence to ASHRAE Standard 90.1-2013 (as described in the previous section), energy savings impact the long-term life cycle cost. In addition to helping reduce GHGs, adherence to energy codes will save money over the life of the building.

***Economic Impact***

Although no study has analyzed the impacts of commercial building energy codes on the national economy, Scott & Niemeyer (2013) studied the economic impact of residential building energy codes in four different states: Minnesota, Nevada, Rhode Island, and Tennessee. Results from the Minnesota study shown in Figure 2.7 demonstrate the benefits that residential building energy codes can have on statewide economies. In the figure, "2010 Housing Starts" refer to the reduced rate of new construction as a result of the Great Recession, whereas the "2000-2010 Average Housing Starts" category more accurately portrays housing rates of 2000 to 2010.

| | IECC 2006 to IECC 2009 | | IECC 2006 to IECC 2012 | | IECC 2009 to IECC 2012 | |
|---|---|---|---|---|---|---|
| **Impact** | **2010 Housing Starts** | **2000-2010 Average Housing Starts** | **2010 Housing Starts** | **2000-2010 Average Housing Starts** | **2010 Housing Starts** | **2000-2010 Average Housing Starts** |
| Housing Starts | 9,840 | 27,470 | 9,840 | 27,470 | 9,840 | 27,470 |
| **Short-Term Impacts** | | | | | | |
| Jobs | 155 | 345 | 470 | 1,310 | 345 | 965 |
| Labor Income (Million 2011$) | 8 | 17 | 23 | 64 | 17 | 47 |
| **Annual Long-Term Impacts** | | | | | | |
| Jobs | 10 | 45 | 65 | 185 | 45 | 125 |
| Labor Income (Million 2011$) | <0.5 | 1 | 2 | 6 | 1 | 4 |

**Figure 2.7: Short-Term and Long-Term Economic Impacts from New Residential Building Energy Codes (Reproduced with Permission from Scott & Niemeyer, 2013)**

The unemployment rate and number of people unemployed in Minnesota from September 2013 (when this study was done) was respectively 4.6% and 136,465 people according to the U.S. Bureau of Labor Statistics (2015). Minnesota is currently under IECC 2012 so the assumption was made that changes from IECC 2009 to IECC 2012 would approximate the Minnesota residential building industry in 2013. The percentage of jobs created due to adopting new residential building energy codes would range from 0.25% to 0.71% of the total unemployed population. While that is hardly a resounding percentage, applying the benefit across the country could mean creating jobs for tens of thousands of people. The jobs created can generally fall into three different categories: direct, indirect, and induced. Direct job creation refers to construction-related jobs in design, building, and inspection; indirect job creation refers to industries supplying inputs to directly affected industries, such as manufacturers and suppliers;

induced job creation refers to local economy benefits as a "result of increased consumer spending based on direct and indirect earnings" (Scott & Niemeyer, 2013). In addition, this study considered only benefits from residential construction and the jobs created would be increased by considering commercial construction. Although this paper mainly discusses the benefits of building energy codes from a GHG emissions perspective, other less obvious benefits of widespread energy code adoption also exist. Once demonstrated and explained, these benefits could be the driving factors to facilitate policy change for building energy codes.

***Integration with Other National Standards (Clean Power Plan)***

In the Clean Air Act (CAA) (written in 1970 and amended in 1990), Section 111 (d) requires that the EPA establish standards of emission performance through the application of the "best system of emission reduction" and a system that "has been adequately demonstrated," leaving the definition of "best" and "adequately demonstrated" up to the EPA. A current policy initiative resulting from this act is the CPP, proposed by the EPA in June of 2014 and finalized in August of 2015, which establishes state-specific emission targets for reducing GHG emissions from existing power plants. A report submitted by Hayes, Ungar, and Herndon (2015) on behalf of the American Council for an Energy-Efficient Economy (ACEEE) details how building energy codes exhibit traits that align with the "best" system of emission reduction. The next few paragraphs will outline how Hayes et al. have determined that building energy codes align with the CPP.

Within the CPP, the EPA qualifies what is meant by "best" (EPA 2014, 37-38):

- The system of emission reduction must be technically feasible.
- The EPA must consider the amount of emissions reductions that the system would generate.
- System costs must be reasonable. The EPA may consider the costs on the source level, the industry-wide level, and, at least in the case of the power sector, on the national level in terms of the overall costs of electricity and the impact on the national economy over time.
- The EPA must also consider that [Clean Air Act] Section 111 is designed to promote the development and implementation of technology.

- The EPA must also consider energy impacts, and, as with costs, may consider them both on the source level and on the nationwide structure of the power sector over time.

In terms of the technical feasibility parameter, courts have clarified the CAA wording to maintain that the feasibility should consider the current state of the system and future projects (Hayes et al., 2015). Many states are currently adopting building energy codes from within the last three code versions, which is detailed further in Chapter 3. Codes will continue to be improved through processes detailed previously in this chapter. Since these processes iteratively build upon past improvements, wider adoption of building energy codes will inevitably lead to further improvement of building energy codes.

In consideration of the amount of reductions available, several studies have shown the effect that codes could have on the amount of GHG emission reductions, including a study presented in Chapter 3. According to the ACEEE, potentially available reductions of $CO_2$ ranges from 76 to 126 MMTCO2 (Hayes et al., 2015). However, these estimates are conservative at best considering that they only account for $CO_2$ and exclude other GHGs.

For the cost-effectiveness measure, building energy codes have been demonstrated to be cost-effective in numerous studies and previously in this chapter. Hayes et al. (2015) reported that a potential net present value savings of $149 billion to $228 billion is possible, including the first cost. These values exceed the costs by an astounding factor of 2.9 to 3.1 (Hayes et al., 2015).

Not as heavily covered in this paper is the effect building energy codes have on new technology. Building energy codes have promoted development of new technology without requiring implementation of specific technologies. Hayes et al. (2015) noted that low-emissivity windows, spray foam insulation, lighting sources and sensors/controls, and air conditioner and boiler economizers have all resulted from updates to building energy codes. Although building energy codes do not require specific technologies to be used, they do indirectly drive further development of technology by increasing efficiency requirements on major pieces of equipment, increasing control requirements, and numerous other requirements (Hayes et al., 2015). This development of technology is due to natural competition in the free market associated with the building industry. As code adoption rates increase, technologically innovative equipment must be manufactured in order to ensure that the products can be utilized throughout the country.

Without building energy codes, new technologies would not be as readily implemented due to the slow "technology diffusion" of the building industry. The typical technology diffusion of the building industry is slow because much of the industry is made up of small businesses where capital for initial purchase of new technologies is not always readily available, leading to purchase of older technologies (Hayes et al., 2015). While building energy codes do not solve the initial capital issue, they provide the regulation necessary for better performing equipment to be purchased, increasing the rate of technology diffusion (Hayes et al., 2015). Because of this, building energy codes have proven to be effective promoters of new technology. Figure 2.8 illustrates this process of technology diffusion.

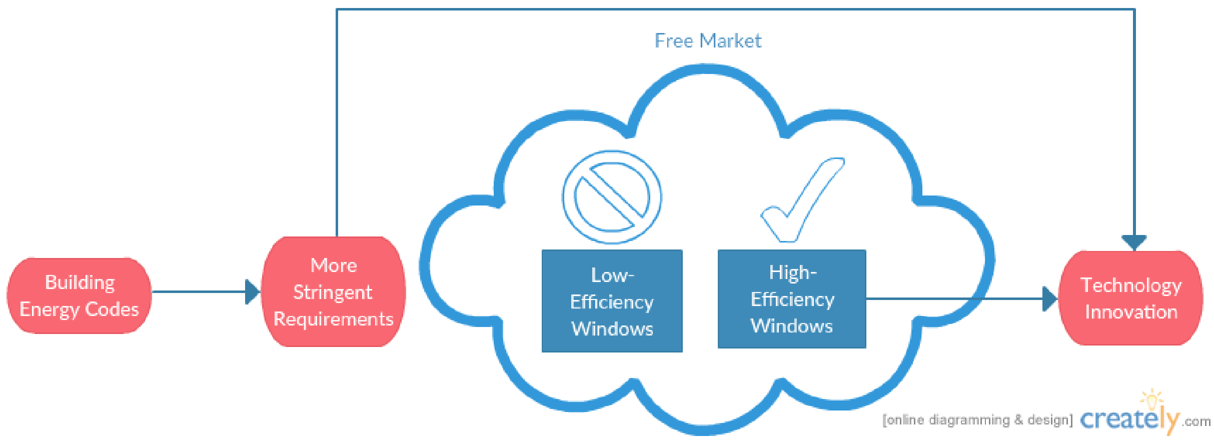



**Figure 2.8: Process of Technology Diffusion in the Building Industry**

Finally, for the last EPA criterion of "best", the energy impact and cost of building energy codes have been discussed in numerous studies and are discussed thoroughly in Chapter 3. Two primary metrics must be defined for further discussion of energy analyses: energy use intensity (EUI) and energy cost intensity (ECI). EUI is a measurement of energy use in British thermal units (BTU) per square foot of conditioned building area per year (Athalye et al., 2013). EUI effectively compares the energy usage of buildings regardless of building size. Likewise, ECI is a measurement of energy cost in dollars per square foot of conditioned building area per year used to compare the energy cost of buildings regardless of building size. In terms of these metrics, Halverson et al. (2014) determined that ASHRAE Standard 90.1-2013 reduces national building source EUI by 8.5% and reduces ECI by 8.7% as compared to ASHRAE Standard 90.1-2010 (the previous version of the code). In addition, ASHRAE Standard 90.1-2010 has shown 18.5% more energy savings than ASHRAE Standard 90.1-2007, and 23% more energy savings than ASHRAE Standard 90.1-2004 (Halverson, Rosenberg, & Liu, 2011; Thornton et al., 2011). Due to iterative development of the standard, the savings should continue to increase. In addition to the pure savings potential, Hayes et al. (2015) noted that a study in the Pacific Northwest demonstrated that building energy codes “were reducing power demand by an average of about 700 megawatts” per year from 2005-2008. This demand savings was an annual cumulative savings at the utility level for the four states encompassing the Pacific Northwest: Montana, Idaho, Oregon, and Washington as compared to the average demand load of 30,000 megawatts per year from 2005 to 2008 (Northwest Power and Conservation Council, 2010). This demand savings demonstrates that building energy codes reduce the total load and demand on a regional power grid, leading to a reduced need for infrastructure changes or expansions.

Now that building energy codes have been shown to align with the EPA’s definition of “best” system of emission reduction, the EPA also qualifies what is considered “adequately demonstrated” (Hayes et al., 2015):

- The system must be well-established
- The system must be consistent with current trends
- The system must currently be relied upon to reduce GHGs

Hayes et al. (2015) assert that building energy codes also meet the criteria of being “adequately demonstrated. In terms of being well-established, 43 states (as of June 2015) have currently adopted a commercial building energy code, proving that a majority of states are following building energy codes (BECP, 2015). The exact state-by-state breakdown is shown in Chapter 3. With the passing of the 2009 American Recovery and Reinvestment Act (ARRA), stimulus funding was offered to states that adopted ASHRAE Standard 90.1-2007 (Hayes et al., 2015). All 50 states accepted these funds and submitted binding commitments to adopt those energy codes (Hayes et al., 2015). Even though not all 50 states have adopted building energy codes yet, the fact that all 50 states have accepted funding shows that the trend towards adopting building energy codes will continue. Since the passing of the 2009 ARRA, some states have adopted statewide codes for the first time and many have also updated their codes (Hayes et al., 2015). Finally, several states are already utilizing building energy codes to meet state GHG emission goals (Hayes et al., 2015).

As demonstrated through the analysis above, building energy codes meet the definition of the “best” system of GHG emission reduction as qualified by the EPA through the CPP. Building energy codes have been proven to be technically feasible, cost-effective, and an effective driver of technology. Additionally, many studies have been done to consider the amount of energy savings possible and the resulting emission reductions from building energy codes. Building energy codes have also met the definition of "adequately demonstrated" as qualified by the EPA through the CPP. Building energy codes are well-established, consistent with current trends, and are currently being utilized to achieve GHG emission reductions. Overall, building energy codes are an ideal system for use within the CPP.

Although several key problems are associated with adoption of current building energy codes, as discussed in the previous chapter, potential benefits of utilizing current building energy codes justify investigation into the feasibility of more widespread adoption and enforcement as a means of reducing national GHG emissions. The next chapter provides further discussion of the specific benefits of building energy codes on a state-by-state basis.

# Chapter 3 - Analysis of State-by-State Savings Potential

In order to demonstrate the emissions reduction potential of increased compliance with current building energy codes, this chapter includes state-by-state analysis utilizing specific data on how each state, and the country overall, could contribute to national GHG reductions. The analysis in this paper includes compilation of energy model data for each ASHRAE Standard 90.1 code for each ASHRAE prototype building throughout the U.S., compilation of square footage of the respective prototype buildings in all states using Commercial Building Energy Consumption Survey (CBECS) data, and application of differences in energy savings between the current code adopted and the most recent code: ASHRAE Standard 90.1-2013. ASHRAE Standard 90.1-2013 is used rather than 2015 IECC for analysis due to more readily available data and studies for ASHRAE Standard 90.1-2013 as compared to the 2015 IECC. Since the two are considered equivalent codes, the results should be similar regardless of which is used for the analysis. In addition, ASHRAE Standard 90.1-2013 is used rather than ASHRAE Standard 189.1 or any various state or jurisdiction-specific stretch codes. This is due to Standard 90.1 being more widely adopted than Standard 189.1 and due to Standard 90.1 being more applicable for a nationwide analysis than state or jurisdiction-specific stretch codes. After determination of energy savings, the cost savings is also determined using the most recent energy prices provided by the EIA. The total amount of energy savings is also used to determine the total amount of GHG reductions made possible by adhering to ASHRAE Standard 90.1-2013 and by utilizing emission values provided by eGRID and the EPA. The purpose of the analysis is to provide the *additional* potential of each state's energy and GHG savings.

This analysis contains specific boundaries. First, due to limited recently published data, accounting for the entire building sector is impossible. Therefore, this analysis accounts for only the commercial building sector, excluding industrial and manufacturing sectors, meaning that this analysis underestimates the potential savings for each state and the entire country. In order to account for the *total* potential energy savings of building energy codes, meaning residential, commercial, industrial and manufacturing, results from other benefit analyses will also be highlighted. The purpose of studying results of all these analyses is, as best as practical, to place the results side-by-side for comparison. When discussing potential GHG emission reductions, general statements are often made that by implementing certain procedures a state or country can save many million tons of CO2e emissions. However, with these general statements, the reader has no frame of reference for what a million ton reduction means. Another common statement resulting from analyses asserts that implementing certain procedures can save a certain percentage of energy or emissions compared to a baseline, but what the baseline represents is not always clear. By placing several different energy savings studies on an even level of comparison, energy savings from the building industry can be put into a national perspective, allowing legislators and lawmakers to gain additional knowledge for determining regulations in the building industry.

Is increased adoption of building energy codes a worthwhile effort? Would increased compliance result in more energy savings compared to increased adoption? If the United States achieved increased adoption and compliance of building energy codes, how much of a difference would this make on the national scale? In order to discuss improvements, this chapter establishes where the energy, emission, and cost savings possible from increased adoption and compliance with building energy codes fits on a national scale. Results in this chapter are then used in the next chapter to propose possible ways to increase adoption and compliance of building energy codes. Essential background information about how the energy savings analysis process is also presented, including factors such as climate, building types, and current code adoption.

## ASHRAE Climate Zones

Climate is an essential consideration when analyzing the effects that an energy code may have on a certain state. For example, measures within an energy standard to increase air-conditioning efficiency will more significantly affect Hawaii than Alaska. Standardized climate zones initially established by the DOE are now used by ASHRAE in order to establish design guidelines based on specific regional climate. These climate zones are shown in Figure 3.1.

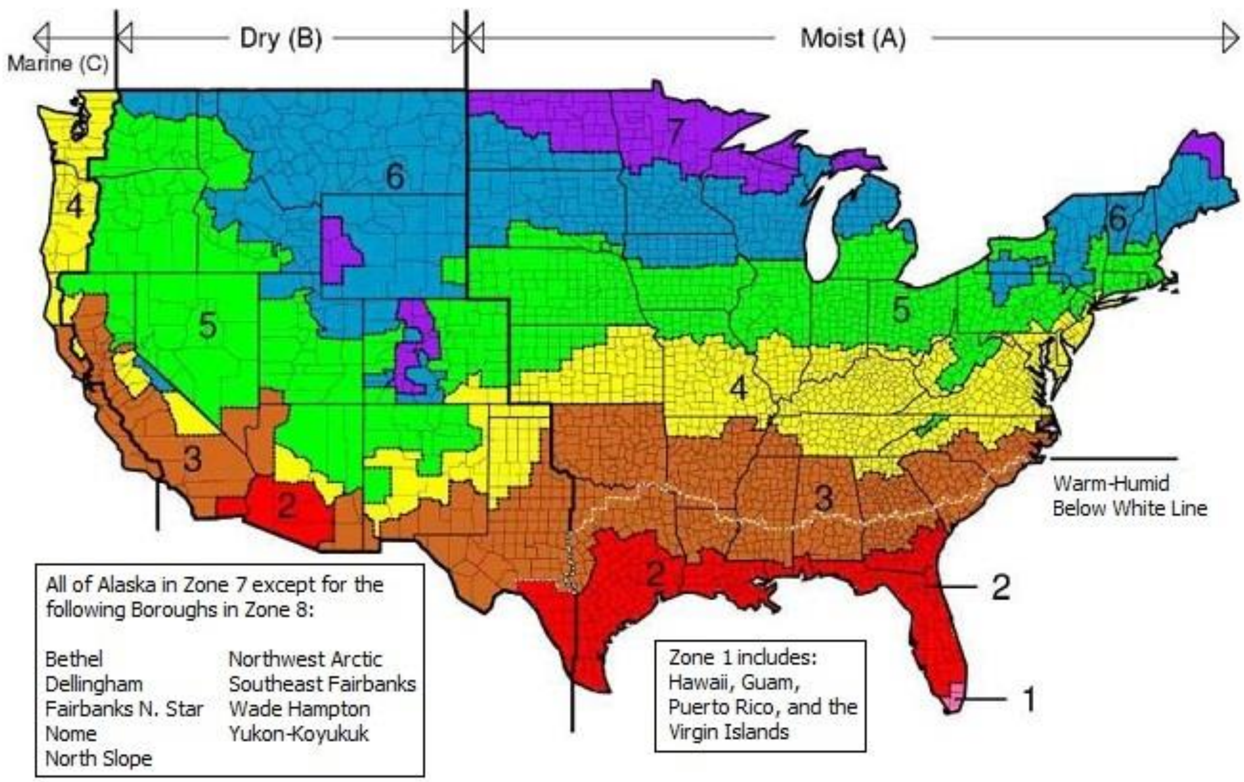



**Figure 3.1: Climate Zone Map (Reproduced with Permission from Athalye et al., 2013)**

As shown in Figure 3.1, the U.S. is comprised of eight temperature-oriented climate zones with three different moisture regimes for a total of 15 climate subzones. Each climate zone has a representative city. The locations representing each subzone are:

- **Miami, Florida (1A)**
  - Very hot, humid
- **Houston, Texas (2A)**
  - Hot, humid
- **Phoenix, Arizona (2B)**
  - Hot, dry
- **Memphis, Tennessee (3A)**
  - Warm, humid
- **El Paso, Texas (3B)**
  - **Warm, dry**

- **San Francisco, California (3C)**
  - Warm, marine
- **Baltimore, Maryland (4A)**
  - Mixed, humid
- **Albuquerque, New Mexico (4B)**
  - Mixed, dry
- **Salem, Oregon (3C)**
  - Mixed, marine
- **Chicago, Illinois (5A)**
  - Cool, humid
- **Boise, Idaho (5B)**
  - Cool, dry
- **Burlington, Vermont (6A)**
  - Cold, humid
- **Helena, Montana (6B)**
  - Cold, dry
- **Duluth, Minnesota (7)**
  - Very cold
- **Fairbanks, Alaska (8)**
  - Subarctic

As the climate zone numbers increase, the climate gets cooler. In order to simplify analysis, ASHRAE examines building performance using weather information within each representative city. Since energy modeling data does not exist for each state in the U.S., the energy performance for each state was approximated by the energy performance for the related climate zone. Furthermore, since most states consist of multiple climate zones, tables in ASHRAE Standard 90.1-2010 (presented in Appendix B - ) were used to determine the number of climate zones by county for each state. This method allowed a close approximation of the climate zone(s) for each state resulting in more accurate energy performance data.

## Prototype Buildings

From 2003 to 2007, the DOE and EIA conducted the CBECS in order to gain additional information about commercial buildings in the United States. For simplification, CBECS used prototype buildings to classify buildings with similar compositions and functions. The prototype buildings used by CBECS were eventually transformed into prototype buildings used by ASHRAE and PNNL. These two sets of prototype buildings differed slightly, as compared in Appendix C - . It should be noted that only new construction is accounted for by use of these prototypes. In order to develop a more accurate picture of energy savings potential through building energy codes, renovations and remodels should be accounted for as well. This research utilized the prototype buildings used by ASHRAE for energy savings analysis due to more readily available data. Figure 3.2 shows building activities and prototypes used for energy analysis.

| Building Type | Prototype building | Prototype Floor Area ($ft^2$) |
|---|---|---|
| Office | Small Office | 5,502 |
| | Medium Office | 53,628 |
| | Large Office | 498,588 |
| Retail | Stand-Alone Retail | 24,692 |
| | Strip Mall | 22,500 |
| Education | Primary School | 73,959 |
| | Secondary School | 210,887 |
| Healthcare | Outpatient Health Care | 40,946 |
| | Hospital | 241,501 |
| Lodging | Small Hotel | 43,202 |
| | Large Hotel | 122,120 |
| Warehouse | Non-Refrigerated Warehouse | 52,045 |
| Food Service | Fast Food Restaurant | 2,501 |
| | Sit-Down Restaurant | 5,502 |
| Apartment | Mid-Rise Apartment | 33,741 |
| | High-Rise Apartment | 84,360 |

**Figure 3.2: Principal Building Activities and Prototypes (Reproduced with Permission from Athalye et al., 2013)**

As shown in Figure 3.2, the prototypes included eight activities for a total of 16 buildings:

- **Office**
  - Small
  - Medium
  - Large
- **Mercantile**
  - Stand-Alone Retail
  - Strip Mall
- **Education**
  - Primary School
  - Secondary School
- **Healthcare**
  - Outpatient
  - Hospital
- **Lodging**
  - Small Hotel
  - Large Hotel
- **Warehouse**
  - Non-refrigerated
- **Food Service**
  - Quick-service
  - Full-service
- **Apartment**
  - Mid-Rise
  - High-Rise

The 16 prototype buildings were modeled for different versions of ASHRAE Standard 90.1 in each climate zone throughout the U.S., resulting in data for energy savings comparisons by PNNL and ASHRAE (Athalye et al., 2013). Although many forms of data were compiled, this research focuses on the EUI of natural gas and electricity. Natural gas and electricity were compared separately due to differing GHG emission values per unit of use. The separate comparison ensures more accurate emissions results. Overall, these 16 prototypes account for 80% of the national commercial building square footage. No reliable energy data exists for the other 20%, so results from this energy savings analysis could be low based on the square footage not accounted for by the prototypes.

CBECS data taken from 2003 to 2007 provided an average annual new construction rate of the 16 prototype buildings by state. In order to allocate square footage to the correct climate zone in each state, a fraction for the counties within that state was used. For example, if a state contains 10 counties, and four of the counties are in Climate Zone 4a, and six are in Climate Zone 5a, the square footage was allocated by multiplying the total square footage by each percentage: 40% for 4a and 60% for 5a.

Several arguments have been made for and against the accuracy of this method. A study done within New York City that accurately dispersed square footage among climate zones, but no significant increase in accuracy was determined (Kneifel and Butry, 2014). Other studies have attempted to allocate square footage based on population growth, arguing that counties with higher population growth should have a higher percentage of annual square footage of new construction (Deru et al., 2011). Although this argument is theoretically sound, results of this allocation method have not varied significantly from the fractional method of allocation (Gilbraith et al., 2014). Because this paper attempts to approximate potential energy savings, the fractional method of allocation is used in this calculation.

## Current Building Energy Code Adoption

Since no national building energy code requirement exists, state and local jurisdictions do not automatically implement energy code requirements. Figure 3.3 shows the building energy code adoption status of all U.S. states and territories.

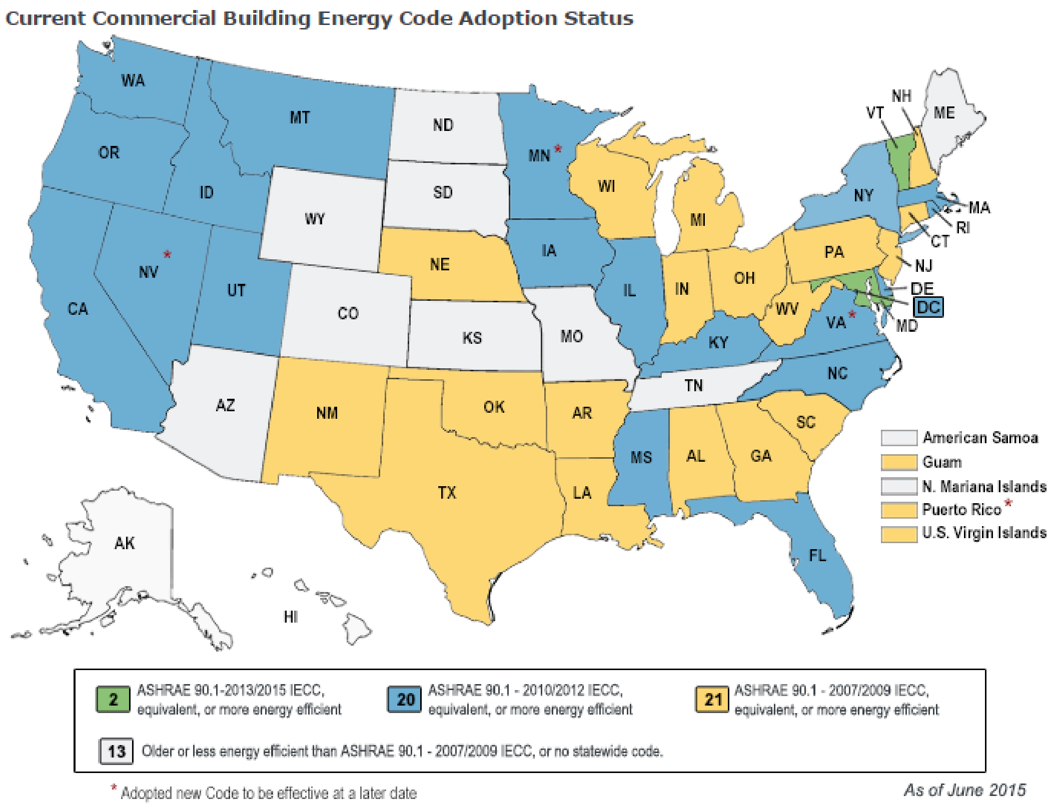



**Figure 3.3: Energy Code Adoption Status Map (Reproduced with Permission from BECP, 2015)**

As shown in Figure 3.3, the building energy code adoption status of each state varies throughout the country:

- **13** states either have a building energy code equivalent that is less efficient than ASHRAE Standard 90.1-2007/2009 IECC, or have no statewide code.
- **21** states have a building energy code equivalent to ASHRAE Standard 90.1-2007/2009 IECC or higher.
- **20** states have a building energy code equivalent to ASHRAE Standard 90.1-2010/2012 IECC or higher.
- **2** states have a building energy code equivalent to ASHRAE Standard 90.1-2013/2015 IECC or higher.

The data showed that a “lag” between current and adopted codes varies state-to-state; this “lag” can be attributed to many difficulties associated with the implementation of building energy codes discussed in Chapter 2. In their analysis of the BECP program effectiveness, ASHRAE had to decide how to account for the spillover effect associated with design and construction in

states that have not adopted an energy code. Spillover effect refers to the tendency of designers and constructors to follow current code practices, whether the current code is adopted in the project location's jurisdiction or not (Livingston et al., 2014). Although the spillover effect cannot be accounted for exactly, Livingston et al. (2014) assumed that a time lag of 10 years was sufficient to appropriately determine current design and construction practices. For example, construction done in 2015 in a state that does not have an adopted energy code is assumed to follow guidelines of the 2006 IECC and ASHRAE Standard 90.1-2004. Based on lags associated by state, Livingston et al. (2014) assumed how states would adopt codes in the future. States were classified into three categories: aggressive, moderate, and slow. An aggressive state adopts a code within 1 to 3 years of the code publication date, a moderate state adopts a code within 4 to 6 years of the code publication date, and a slow state either requires more than 6 years to adopt a code or does not adopt a code at all (Livingston et al., 2014). These classifications help determine realistic expectations for states when adopting a new or more current code. A list of the states are currently classified is shown in
Table 3.1.

**Table 3.1: State Classification for Future Commercial Energy Code Adoption (Reproduced with Permission from Livingston et al., 2014)**

| Aggressive | Moderate | Slow |
|---|---|---|
| • California<br>• Florida<br>• Georgia<br>• Illinois<br>• Iowa<br>• Maryland<br>• Massachusetts<br>• New Hampshire<br>• New York<br>• North Carolina<br>• Oregon<br>• Rhode Island<br>• Utah<br>• Washington | • Connecticut<br>• Delaware<br>• District of Columbia<br>• Idaho<br>• Kentucky<br>• Louisiana<br>• Maine<br>• Michigan<br>• Montana<br>• Nebraska<br>• Nevada<br>• New Jersey<br>• New Mexico<br>• Ohio<br>• Pennsylvania<br>• South Carolina<br>• Texas<br>• Vermont<br>• Virginia<br>• Wisconsin | • Alabama<br>• Alaska<br>• Arizona<br>• Arkansas<br>• Colorado<br>• Hawaii<br>• Indiana<br>• Kansas<br>• Minnesota<br>• Mississippi<br>• Missouri<br>• North Dakota<br>• Oklahoma<br>• South Dakota<br>• Tennessee<br>• West Virginia<br>• Wyoming |

Although utilization of the adopted energy code of each state is a decent approximation of energy savings, since individual counties and jurisdictions have the ability to adopt their own energy code, overall results may differ slightly from reality. A state-by-state adoption methodology must be used due to lack of supporting data. Even though adoption data approximates construction practices within each state, utilization of compliance rates is ideal in order to accurately portray the percentage of code-compliant new construction square footage. Unfortunately, no reliable data exists on the amount of new construction in compliance with the adopted energy code. A study by Stellberg (2013) determined that a compliance rate could not be determined on a state-by-state basis. Instead, the study gave a range of potential savings, varying from a worst-case scenario of 25% compliance to a best-case scenario of 75% compliance (Stellberg, 2013). In addition to differing compliance rates, Stellberg (2013) recommended application of a non-compliance energy loss factor, assuming "a default energy loss factor of 15% for each state (i.e., a non-compliant building uses 15% more energy than an identical building constructed to code). This loss factor is consistent with the average non-compliance impacts found in baseline compliance evaluation." This method is used in this paper's energy analysis.

## Calculation Methodology

Utilizing information about climate zones, prototype buildings, and current building energy code adoption, an approximate calculation was developed for each state's energy savings potential if it were to adopt and enforce ASHRAE Standard 90.1-2013. The difference in potential between current and most recent codes is significant because the difference illustrates the benefit of proactive adoption and stringent enforcement.

Several steps were taken in order to estimate the potential differences between current and most recent building energy codes. Equations used for all steps are shown and explained in Appendix D - First, electricity and natural gas EUI values for ASHRAE Standard 90.1-2004 through ASHRAE Standard 90.1-2013 were gathered for each prototype building across all climate zones. Next, square footage was gathered for each prototype building in each state according to the 2003 to 2007 CBECS. EUI values were then multiplied by corresponding square footage to obtain total energy usage in BTUs for the appropriate version of ASHRAE Standard 90.1. Energy savings from complying and enforcing ASHRAE Standard 90.1-2013 for each state was then determined by subtracting 90.1-2013 energy usage from the current state adopted energy code. If the state had no energy code, ASHRAE Standard 90.1-2004 values were used because this code is a respectable approximation of current unrestricted construction techniques in those states based on lag discussed by Livingston et al. (2014). If a state was currently adopting ASHRAE Standard 90.1-2013 or better, no savings were accounted for. In addition, a compliance rate ranging from a worst-case scenario of 25% to a best-case scenario of 75% was used in order to account for differing compliance rates throughout the U.S., as well accounting for a default energy loss factor of 15%. As a result, a range of energy savings in BTU for natural gas and electricity attributed to compliance with ASHRAE Standard 90.1-2013 was determined for each state. Extended results of this study are presented in Appendix D - . A national summary in TBtu ($10^{12}$ BTU) is shown in Table 3.2.

**Table 3.2: National Summary of Energy Savings for Adoption and Compliance of ASHRAE Standard 90.1-2013**

| National Summary | | | | |
|---|---|---|---|---|
| Total U.S. Savings | Low Case | | High Case | |
| | Energy Savings (TBtu) | Energy Savings (%) | Energy Savings (TBtu) | Energy Savings (%) |
| Electricity | 8.40 | 5.66% | 25.20 | 17.0% |
| Natural Gas | 1.02 | 5.78% | 3.07 | 17.3% |
| Total | 9.42 | 5.72% | 28.27 | 17.2% |

## Emission Analysis

GHG emissions savings were accurately determined because EUI data were compiled for electricity and natural gas. For electricity, eGRID provides emission factors for all GHGs by state, making the calculation very simple. Each state's energy savings in BTU from the previous section is converted into a kilowatt-hour unit and then multiplied by the relevant state emission factor to be converted into total MTCO2e. For natural gas, the calculation is the same as the electricity calculation except a base emissions factor of 0.0053208 MTCO2e/therm is used because the amount of natural gas emissions does not vary significantly based on plant type and location as with electricity. Each state's natural gas savings is converted into a therm unit and then multiplied by the emissions factor to be converted into total MTCO2e. State-by-state results of this analysis and further explanations of the equations are presented in Appendix E - . A national summary is shown in Table 3.3.

**Table 3.3: National Summary of Emission Savings for Adoption and Compliance of ASHRAE Standard 90.1-2013**

| National Summary | | |
|---|---|---|
| Total U.S. Savings | Low Case | High Case |
| | Emission Savings (MMTC02e) | Emission Savings (MMTC02e) |
| Electricity | 1.77 | 5.31 |
| Natural Gas | 0.05 | 0.16 |
| Total | 1.82 | 5.47 |

## Cost Analysis

The goal of this paper is to highlight the potential reductions of national GHG emissions related to further adoption of current building energy codes. In addition to the benefits of increased building energy code adoption, much can also be learned from observing the disadvantages of increased adoption in the form of increased costs of implementation. One of the most critical aspects of energy savings analyses is the cost impact. This impact can be evaluated on many levels, with no suggested or standard implementation of large-scale cost analysis. In order to accurately demonstrate cost advantages of building energy codes, analysis that details total energy savings and total cost of implementation is preferred. However, accurate first-cost analysis is difficult on a nationwide basis because only limited data exists for cost implementation of the latest energy codes. As discussed in Chapter 2, the cost-effectiveness of ASHRAE Standard 90.1-2013 has been analyzed, but only across a handful of climate zones and prototype buildings. Although it utilized only a smaller sample size, the analysis covered 75% to 80% of national commercial building square footage and provided a relatively accurate depiction of national first-cost effectiveness. However, since accurate first-cost data is not available across all prototype buildings and climate zones, true life cycle cost analyses cannot be performed on a national scale.

Consideration of what scenarios are being analyzed and who the end-users are is crucial when performing cost analyses. For example, a cost analysis for a building owner may focus on a specific first cost to their building and utility cost savings for increased energy efficiency measures, resulting in a simple payback from the scenario. However, when focusing on a macro scale, such as a state and national level, the same details are not relevant. For example, a state government that adopts the latest energy code is most likely not overly concerned with the payback on one specific large hotel; it wants to know how adopting the latest code affects the state on a statewide scale. In addition to the priority of cost-effective energy code adoption, the level of analysis should cover more than first cost. However, every scenario for every owner is different, so this specific analysis cannot be conducted on a statewide scale. Consequently, most macro-scale energy analyses focus more on energy savings rather than the cost of implementation.

Due to lack of first cost data and differences in end-users, a cost implementation analysis was not performed in this research. Energy cost savings were calculated by multiplying previously determined electricity and natural gas energy savings by state-dependent utility sale costs. Because first cost is not included in these results, the actual cost savings will not be as high as calculated. However, each version of ASHRAE Standard 90.1 was determined to be cost-effective at an individual building level, so costs associated with adoption of ASHRAE Standard 90.1-2013 are not expected to be larger than the potential savings. Results and further explanations of the equations used are presented in Appendix F - . A national summary is shown in Table 3.4.

**Table 3.4: National Summary of Cost Savings for Adoption and Compliance of ASHRAE Standard 90.1-2013**

| National Summary | | |
|---|---|---|
| Total U.S. Savings | Low Case | High Case |
| | Cost Savings (Million $) | Cost Savings (Million $) |
| Electricity | 241.45 | 724.36 |
| Natural Gas | 8.33 | 24.99 |
| Total | 249.79 | 749.36 |

## Comparison with Other Results

After establishing available potential from adopting and complying with ASHRAE Standard 90.1-2013 these energy and emissions savings must be compared to other industry benchmarks in order to determine the meaning of this additional potential. A comparison of the energy and emissions savings potential to the total amount of sales for electricity and natural gas is the optimal way to see determine how the energy and emissions savings potential calculated compares to national energy usage and emissions. Sales data was taken for the comparison from the EIA for the year 2013, the most recent year with complete data. A national summary is presented in Table 3.5.

**Table 3.5: National Summary of Energy Savings for Adoption and Compliance of ASHRAE Standard 90.1-2013 vs. Total Sales for 2013**

| National Summary | | | | | |
|---|---|---|---|---|---|
| | Total U.S. Sales | Low Case | | High Case | |
| | | Energy Savings | Energy Savings (%) | Energy Savings | Energy Savings (%) |
| Electricity (MWH) | 3,725,063,721 | 2,461,431 | 0.07% | 7,384,294 | 0.20% |
| Natural Gas (MMBTU) | 26,685,693,575 | 1,024,270 | 0.004% | 3,072,809 | 0.01% |

As shown in the comparison, the amount of energy savings calculated was significantly less than total annual sales for both electricity and natural gas. The comparison also shows that adoption and compliance with ASHRAE Standard 90.1-2013 resulted in more savings for electricity than natural gas. Table 3.6 presents a national estimate in terms of emissions.

**Table 3.6: National Summary of Emission Savings for Adoption and Compliance of ASHRAE Standard 90.1-2013 vs. Emissions from Total Sales for 2013**

| National Summary | | | | | |
|---|---|---|---|---|---|
| | Total 2010 U.S. Estimate (MMTCO2e) | Low Case | | High Case | |
| | | Emission Savings (MMTCO2e) | Emission Savings (%) | Emission Savings (MMTCO2e) | Emission Savings (%) |
| Electricity | 2,664 | 1.77 | 0.07% | 5.31 | 0.20% |
| Natural Gas | 1,420 | 0.05 | 0.004% | 0.16 | 0.01% |

According to the summary, the emissions savings potential from increasing adoption and compliance accounts for an almost negligible portion of national emissions. However, commercial buildings comprise only a portion of the end-use of sales at 36% of electricity consumed and 14% of natural gas consumed (EIA, 2015, September). Table 3.7 and Table 3.8 show results for nationwide energy savings and emissions savings for commercial buildings only.

**Table 3.7: National Summary of Energy Savings for Adoption and Compliance of ASHRAE Standard 90.1-2013 vs. Commercial Building Industry Energy Sales for 2013**

| National Energy Savings Summary | | | | | |
|---|---|---|---|---|---|
| | Total U.S. Sales | Low Case | | High Case | |
| | | Energy Savings | Energy Savings (%) | Energy Savings | Energy Savings (%) |
| Electricity (MWH) | 1,327,101,000 | 2,461,431 | 0.19% | 7,384,294 | 0.56% |
| Natural Gas (MMBTU) | 3,278,856,000 | 1,024,270 | 0.031% | 3,072,809 | 0.09% |

**Table 3.8: National Summary of Emissions Savings for Adoption and Compliance of ASHRAE Standard 90.1-2013 vs. Commercial Building Industry Retail Sales for 2013**

| National Emissions Savings Summary | | | | | |
|---|---|---|---|---|---|
| | Total 2010 U.S. Estimate (MMTCO2e) | Low Case | | High Case | |
| | | Emission Savings | Emission Savings (%) | Emission Savings | Emission Savings (%) |
| Electricity | 961 | 1.77 | 0.18% | 5.31 | 0.55% |
| Natural Gas | 174 | 0.05 | 0.031% | 0.16 | 0.09% |

Although the savings potential is still almost negligible compared to commercial energy use and emissions, the scale of how savings are interpreted should be continuously adjusted to make the comparison of energy and emissions savings to usage more representative. A way make the comparison more representative is to compare the energy and emissions savings potential to the amount of estimated savings that the BECP procured in 2012. Results of these comparisons are shown in Table 3.9 and Table 3.10.

**Table 3.9: National Summary of Energy Savings for Adoption and Compliance of ASHRAE Standard 90.1-2013 vs. BECP Energy Savings for 2012**

| National Energy Savings Summary | | | | | |
|---|---|---|---|---|---|
| | Total BECP Savings | Low Case | | High Case | |
| | | Energy Savings | Energy Savings (%) | Energy Savings | Energy Savings (%) |
| Electricity and Natural Gas (TBTU) | 336 | 9 | 2.80% | 28 | 8.41% |

**Table 3.10: National Summary of Emissions Savings for Adoption and Compliance of ASHRAE Standard 90.1-2013 vs. BECP Emissions Savings for 2012**

| National Emissions Savings Summary | | | | | |
|---|---|---|---|---|---|
| | Total BECP Savings | Low Case | | High Case | |
| | | Emission Savings | Emission Savings (%) | Emission Savings | Emission Savings (%) |
| Electricity and Natural Gas (MMTCO2e) | 28 | 2 | 6.59% | 5 | 19.76% |

The results show that this energy and emissions savings potential comprises a healthy portion of the savings the BECP currently estimates. Another eye-opening comparison is to compare the energy and emissions savings potential to the amount of energy savings that has been estimated by Stellberg (2013) if current compliance rates increased but adoption rates stayed the same. This comparison between the energy and emissions savings potential and the results from Stellberg's study is shown in Table 3.11.

**Table 3.11: National Summary of Energy Savings for Adoption and Compliance of ASHRAE Standard 90.1-2013 vs. Energy Savings from Enhanced Code Compliance**

| National Energy Savings Summary | | | | |
|---|---|---|---|---|
| | Low Case | | High Case | |
| | Energy Savings (TBtu) | Percentage Increase (%) | Energy Savings (TBtu) | Percentage Increase (%) |
| Enhanced Code Compliance (from Stellberg) | 2.83 | [redacted] | 8.48 | [redacted] |
| Enhanced Code Compliance AND Adoption (from T3.2) | 9.42 | 233% | 28.27 | 233% |

Both savings scenarios can be compared directly because Stellberg utilizes the low and high case methodology. Results expectedly show the savings potential to be notably higher than if only compliance rates were increased. The potential could also be higher because Stellberg (2013) removed "beyond-code" square footage from the CBECS square footage used in the study; entire CBECS square footage was used in this research because of lack of available beyond-code square footage data. The significance of this difference in square footage is unknown. While accounting for this difference in square footage would make the savings potential difference smaller, it is still helpful to see how the potential discovered in this paper compares to other relevant studies.

In summary, although building energy codes exhibit some potential for reducing national GHG emissions, the potential reductions are not enough to make a large impact on the national scale. However, as demonstrated by comparisons made above, it could still be beneficial to push for faster code adoption and enhanced compliance. As evidenced by the cost-effectiveness of building energy codes, improved rates of adoption and compliance would bring more financial benefit than cost to building owners over time. Chapter 4 explains these results and potential future scenarios for national GHGs.

# Chapter 4 - How Can Building Codes Fulfill their Potential?

Even though improved building energy code adoption comprises a relatively small portion of national GHG emission reductions, as demonstrated by results in Chapter 3, the GHG emission reductions possible from enhanced adoption are not insignificant and should not be dismissed as such. If building energy codes are cost-effective and they partially contribute to

GHG emission reductions, why do adoption rates lag? No single answer exists; most experts agree that the adoption rates lag because of a combination of first cost, lack of public belief, the code adoption process, inadequate enforcement, low priority, and lack of adequate funding as summarized in Chapter 2. This chapter discusses multiple hypothetical solutions and policies that could help the United States realize the available potential energy savings.

## Social Costs

Energy savings analyses often fail to account for the social cost of pollution. The effects of pollution are difficult to monetize, and varying opinions exist as to whether or not to include these social costs in analyses. Because no agreed-upon standard exists for evaluating social costs, only accounting for the private benefits, such as energy cost savings, is reasonable. However, if social costs are ignored, a completely separate component of the true cost of pollution is unaccounted for. Social costs occur "when any costs of production or consumption are passed on to third parties, like future generations or society at large" (Hohmeyer, 2002). Social costs are significant in market economies such as the energy system because "decisions are determined by market prices and politics" (Hohmeyer, 2002). If true cost is not reflected in market prices, policymakers may make underinformed decisions. Ignoring the social cost of high energy consumption directly relates to the "non-sustainable energy use in the past" (Hohmeyer, 2002). This non-sustainable energy use has occurred partly due to lack of evidence and knowledge regarding the social cost of pollution (Hohmeyer, 2002). Although no consensus on how to calculate the social cost of pollution currently exists, sufficient evidence is now available to confirm that social costs do exist.

The most popular and well-known air pollution damage calculator is known as the Air Pollution Emission Experiments and Policy (APEEP) model. The model is referred to as an "integrated assessment model" that "connects emissions of air pollution through air-quality modeling to exposures, physical effects, and monetary damages" (National Academies Press [NAP], 2010). Specifically, damages from $SO_2$, VOC, $NO_x$, $PM_{2.5}$, $PM_{10,}$ and $NH_3$ are calculated in terms of dollars-per-ton. These damages include "adverse effects on human health, reduced yields of agricultural crops and timber, reductions in visibility, enhanced depreciation of man-made materials, and damages due to lost recreation services" (National Academies Press [NAP], 2010). The most recent version of the APEEP model is the AP2. Gilbraith et al. (2014) pointed out that the AP2 is the most extensively used model in research and the best model for estimating social costs due to pollution.

The AP2 allows for improved accounting of social costs, resulting in a much more accurate picture than previously available for actual energy costs. Because these social costs are not accounted for in the market price of energy, no additional incentive exists for implementation of energy efficient strategies as the benefits of energy efficiency do not outweigh the market price cost. The DOE has attempted to motivate the states to implement energy efficiency options such as current building energy codes by offering incentives such as technical and monetary assistance based on the 2009 ARRA, as discussed in Chapter 2. Unfortunately, because the DOE allocation equation overlooks social costs, the amount of assistance provided could be described as undervalued and disproportionately distributed. In fact, Gilbraith et al. (2014) determined that approximately $800 million in benefits is lost in the first year that updating or adopting energy codes (in this study, ASHRAE Standard 90.1-2010 from ASHRAE Standard 90.1-2007) is delayed. If adoption is delayed for five years, then the cumulative benefits lost are approximately $3.5 billion (Gilbraith et al., 2014).  This pales in comparison to the current benefits offered of $26 million (Gilbraith et al., 2014). While policymakers would not have to increase incentives to that degree, the allocation equation should be examined to determine whether the incentives offered can get closer to the possible benefits. In addition, by taking into account social cost, the incentives can be distributed properly, ensuring that the amount of energy saved per dollar spent is optimized. It should be noted that an increase in the amount of incentives offered by the DOE will not necessarily mean that states will adopt current building energy codes. However, given the widespread adoption of ASHRAE Standard 90.1-2007 following an incentive increase from $26 million to $3 billion due to the 2009 ARRA, it is clear that the states are aware of the DOE incentive program (Gilbraith et al., 2014).  Figure 4.1 shows a comparison of current benefits offered in relation to the potential of social benefits.

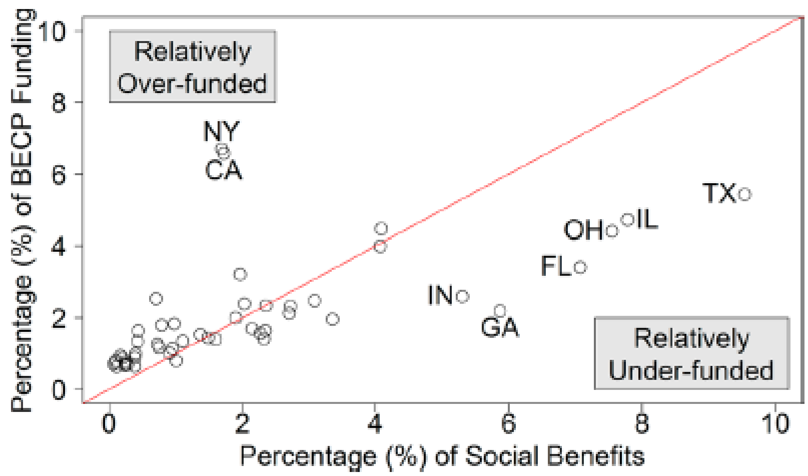



**Figure 4.1: Graph of Percentage of BECP Funding vs. Percentage of Social Benefits (Reproduced with Permission from Gilbraith et al., 2014, Copyright 2014 American Chemical Society)**

If the allocation equation was perfectly aligned in terms of social benefits, all states would fall along the line drawn on the graph. However, several states are relatively underfunded, including Indiana, Georgia, Florida, Ohio, Illinois, and Texas. Two of the leading states in terms of energy efficiency, New York and California, are relatively overfunded. This excess funding could explain why those states have had such successful energy efficiency campaigns. By fixing the allocation equation to account for social costs, states could realize energy benefits lost through lack of funding.

## Benchmarking

Data from surveys such as the 2003 to 2007 CBECS, the survey used for a majority of the study in this paper, must be kept updated. The next version of CBECS (2012) is expected to be fully released by February 2016 (EIA, 2015). Updated energy usage surveys allow legislators and policymakers to obtain accurate understanding of the country's current energy usage and how recently implemented policies affect energy usage. Currently, several cities have benchmarking requirements, including Washington, D.C.; Austin, Texas; New York, New York; Seattle, Washington; and San Francisco, California (Palmer & Walls, 2015). In each of these cities, building owners are "required to submit monthly electric and natural gas bills and certain building characteristics, including gross square footage, year built, and operating hours to the administering agency in the city" (Palmer & Walls, 2015). Implementation of benchmarking requirements in more cities will provide policymakers with a larger amount of data for decision making potentially resulting in more-informed decisions.

A reputable example of successfully implementation of benchmarking is Local Law 84 in New York, New York. Local Law 84 of 2009 “requires all privately-owned properties with individual buildings over 50,000 square feet or with multiple buildings with a combined square footage over 100,000 square feet to annually measure and report their energy and water use” (New York City Mayor’s Office of Long-Term Planning and Sustainability [OLTPS], 2013). For the 2010 calendar year, data was collected for a total of 1.7 billion square feet, a total equal to the building area in Boston and San Francisco combined (OLTPS, 2013). Data collected from Local Law 84 has recently been used to mark the current state of building energy consumption and to analyze changes and trends over a period of time. In addition, requiring only large buildings to document energy usage provides insight into energy intensive buildings as opposed to smaller buildings with relatively small energy footprints. Although small buildings could have high EUIs, large buildings constitute a majority of the energy footprint in New York City. The distinction between large and small buildings is essential because every building cannot practically be required to document total energy usage.

This energy usage data should be used for benefit of the buildings submitting the reports as well as large studies that encompass entire jurisdictions or multiple states. In a roundtable discussion on energy efficiency, building owners appreciated the idea of data collection, but confirmed that the information often goes unutilized once collected (JCIBE, 2013, June). Benchmarking, therefore, must involve data collection and provide actionable processes from the data. A JCIBE (2013, June) survey showed that the frequency of collection versus the frequency of analysis is not correlated. Many organizations are beginning to collect data more frequently, but that data is being analyzed less often than the data is collected. This lack of analysis could be a symptom of data inundation without specific protocol for how to process and use the data.

The roundtable also discussed collecting and analyzing the correct and relevant data metrics; the same metrics do not fit all buildings. For example, a company that leased out a section of their office to another company will have a higher EUI that year than the previous year. However, the higher EUI in this case should not be a negative sign, instead it should be normalized for the increased occupant density in order to provide a metric that can be easily compared to previous years before the occupant increase. Energy management services, which provide outside expertise on data collection, data use, and meaningful responses to the information gathered should be better utilized by companies (JCIBE, 2013, June).

The roundtable also discussed ways to translate the energy usage data for different audiences. The building owners asserted that "data isn't information – it has to be translated into relevant information" (JCIBE, 2013, June). For example, data on the financial worth of the building may not be relevant to an engineer, but it is relevant to a CFO. In contrast, the EUI of an open office floor plan may not be relevant to a CFO, but an engineer can effectively utilize that data. Putting the data into relevant terms for the corresponding audience is essential to ensure that data is properly utilized (JCIBE, 2013, June). The information available from benchmarking can then be compared to meaningful industry standards, thereby providing incentive and motivation to improve energy efficiency.

Another benefit of benchmarking that was not mentioned in the roundtable discussion is the impact that benchmarking can have on market conditions and responses. The positive economic impact that building energy codes can have for building owners has already been discussed in Chapter 2; benchmarking, in conjunction with the adoption of current building energy codes, can further enhance that economic impact. A study by Burr, Majersik, and Stellberg (2012) highlighted two specific benefits that result from benchmarking: recognition of energy efficiency in the marketplace and increased awareness of building owners regarding energy efficiency improvement opportunities. When energy efficiency is recognized in the real estate marketplace, demand is created for potential tenants, investors, and other real estate participants. This demand consequently encourages competition, thus providing economic incentive for building owners to invest in energy efficiency measures. Benchmarking also informs building owners of specific opportunities for improvement, allowing owners the opportunity to invest in capital upgrades for energy efficiency in their buildings. This increased investment in energy efficiency directly and indirectly produces demand for labor in energy efficiency fields. In addition, the positive economic effect of benchmarking reproduces itself over the subsequent years, because dollars saved resulting from energy efficiency are able to be reinvested into the industry. A summary of study results from Burr et al. (2012) are shown in Table 4.1.

**Table 4.1: Summary of Employment Benefits from Energy Efficiency Upgrades (Reproduced with Permission from Burr et al., 2012)**

| | Multifamily | | Commercial | | Total |
|---|---|---|---|---|---|
| | Capital Upgrade Expenditures (million $) | Employment From Capital Upgrade Expenditures (# jobs) | Capital Upgrade Expenditures (million $) | Employment From Capital Upgrade Expenditures (# jobs) | Total Employment From Capital Upgrade Expenditures (# jobs) |
| Sum 2012-2035 | $ 665.51 | 8,924 | $ 15,309.85 | 198,040 | 206,965 |
| 2012 | $ 8.55 | 115 | $ 127.16 | 1,645 | 1,760 |
| 2013 | $ 12.96 | 174 | $ 192.52 | 2,490 | 2,664 |
| 2014 | $ 17.43 | 234 | $ 259.42 | 3,356 | 3,589 |
| 2015 | $ 22.00 | 295 | $ 328.32 | 4,247 | 4,542 |
| 2016 | $ 26.66 | 357 | $ 399.26 | 5,165 | 5,522 |
| 2017 | $ 26.95 | 361 | $ 472.31 | 6,110 | 6,471 |
| 2018 | $ 27.27 | 366 | $ 547.46 | 7,082 | 7,447 |
| 2019 | $ 27.62 | 370 | $ 624.40 | 8,077 | 8,447 |
| 2020 | $ 27.98 | 375 | $ 702.97 | 9,093 | 9,469 |
| 2021 | $ 28.36 | 380 | $ 711.94 | 9,209 | 9,590 |
| 2022 | $ 28.73 | 385 | $ 720.88 | 9,325 | 9,710 |
| 2023 | $ 29.13 | 391 | $ 729.88 | 9,441 | 9,832 |
| 2024 | $ 29.54 | 396 | $ 739.03 | 9,560 | 9,956 |
| 2025 | $ 29.95 | 402 | $ 748.33 | 9,680 | 10,082 |
| 2026 | $ 30.37 | 407 | $ 757.73 | 9,802 | 10,209 |
| 2027 | $ 30.78 | 413 | $ 767.21 | 9,924 | 10,337 |
| 2028 | $ 31.20 | 418 | $ 776.70 | 10,047 | 10,465 |
| 2029 | $ 31.61 | 424 | $ 786.20 | 10,170 | 10,594 |
| 2030 | $ 32.03 | 430 | $ 795.70 | 10,293 | 10,722 |
| 2031 | $ 32.45 | 435 | $ 805.26 | 10,416 | 10,852 |
| 2032 | $ 32.87 | 441 | $ 814.86 | 10,541 | 10,981 |
| 2033 | $ 33.28 | 446 | $ 824.47 | 10,665 | 11,111 |
| 2034 | $ 33.69 | 452 | $ 834.09 | 10,789 | 11,241 |
| 2035 | $ 34.10 | 457 | $ 843.75 | 10,914 | 11,372 |

The economic impact of energy efficiency expenditures was studied for both multifamily and commercial applications. As evidenced by the results, the compounding effect on employment, especially in the first 8 years after expenditures, is striking.

Benchmarking alone is not a solution to the GHG emission reductions problem, but a benchmarking policy used in conjunction with current building energy codes could yield GHG emission reductions greater than either benchmarking or building energy codes could provide separately. Individually, the impact that either benchmarking or building energy codes could provide on GHG emission reduction becomes an issue of regulation versus economic incentive. Building energy codes are a regulatory measure, thereby requiring enforcement. Regulation is effective in the short-term, but long-term effectiveness of regulatory measures often dwindles (Williams, 2015). This is because regulation reduces flexibility in how to reduce GHGs and consequently reduces innovative methods for reducing GHGs (Williams, 2015). However, economic incentive does not require enforcement since natural competition of the free market produces change (Williams, 2015). Economic incentive can provide a greater long-term reduction of GHGs, because the industry is encouraged to pursue energy efficiency measures and innovate in order to capture the incentive (Williams, 2015). However, incentive does not effectively provide GHG emission reduction in the short-term because innovation requires time. (Williams, 2015). It is unlikely for either regulation or economic incentive to be successful by themselves, so hybrid-approaches with characteristics of both are often preferred (Williams, 2015). The benefits of regulation and economic incentive could be captured utilizing benchmarking in conjunction with building energy codes.

## Increased Utility Role

One of the most significant relationships for building energy code adoption is the relationship between the utility companies and the code enforcement agencies. For reasons discussed in Chapter 2, utility companies are motivated to improve energy efficiency measures to lower demand on infrastructure and avoid expensive repairs, replacements, and additions. Many states have implemented policies to increase energy efficiency in utility plants. These policies, commonly referred to as energy efficiency resource standards (EERS), can be implemented for electricity or natural gas and are usually achieved through customer programs and incentives. As of April 2015, 24 states have EERS for electricity savings and 15 of those states also have policies for natural gas (ACEEE, 2015). EERS have been shown to be effective because states with an EERS achieved electricity savings of 1.1% on average compared to a savings of 0.3% for states without an EERS (ACEEE, 2015).

Because no national standard exists for EERS, details and results of the EERS, referred to as portfolios, can vary from state to state (Misuriello, Kwatra, Kushler & Nowak, 2012). Some of these variances include how stringent with building energy codes or regulatory developments portfolios are and the means and methods for achieving savings. In particular, utility involvement in building energy code initiatives tends to vary throughout the United States. In general, ACEEE has shown that states with more stringent portfolios have more advanced building energy code programs (Misuriello et al., 2012).

Utility involvement in building energy codes has many advantages. First, because building energy codes are mandatory in states in which codes are adopted and enforced, program participation tends to be higher than traditional voluntary programs associated with EERS (Misuriello et al., 2012). Second, the amount of energy savings is substantial, as detailed in Chapter 3. Finally, a higher level of utility involvement could lead to more advanced code compliance data, which could enhance utility system planning (Misuriello et al., 2012).

Utilities have vast experience estimating energy consumption for load and conservation forecasts, but have fairly little empirical data when accounting for shortfalls in code compliance (Misuriello et al., 2012). The limited studies done "suggest that the savings shortfall can be substantial, perhaps 5%-8% in residential and commercial buildings" (Misuriello et al., 2012). A study shown earlier in this paper from Stellberg (2013) estimated 75% to be a high compliance, thereby making the shortfall closer to 25%. Regardless of what the shortfall actually is, it only magnifies as the newly constructed buildings of today become the existing buildings of tomorrow and continue to affect the load forecasts annually (Misuriello et al., 2012). A higher involvement in code compliance evaluation studies would increase forecast accuracy and illustrate the current level of code compliance, simplifying determination of whether or not to increase efforts in code support. Increased code support will also result in more accurate load forecasts and a lower demand on utility infrastructure (Misuriello et al., 2012).

Promising methods for utility involvement in energy codes have been developed and enacted by a few model states. California, a leader in energy efficiency, has developed two key processes that enhance utility involvement: Codes and Standards Enhancement (CASE) reports and an evaluation and attribution model. CASE reports analyze "the costs and benefits of pursuing specific energy saving technology measures and help the California Energy Commission justify changes to California's Administrative Codes Title 20 (Appliance Codes) and Title 24 (Building Codes)" (Cooper & Wood, 2011). In other words, CASE reports provide a standardized report to reference when making changes to any code, ensuring that the difficult process of adoption is as smooth and efficient as possible. Furthermore, specific costs and benefits are stated in the reports, allowing for more accurate life cycle cost analyses for owners to use when beginning new projects. The evaluation and attribution model allows utilities to take credit for their efforts in encouraging energy code adoption (Cooper & Wood, 2011). The model involves "identifying the net energy savings from utility actions" that includes "discounting for factors such as compliance and naturally occurring market changes that would have occurred without utility efforts" (Cooper & Wood, 2011). The model includes five steps: potential savings, compliance, normally occurring market adoption (NOMAD), attribution, and allocation analyses (Cooper & Wood, 2011). Each step is outlined below (Cooper & Wood, 2011):

- Potential savings analyses highlight the benefits of adopting a more stringent code than the current code adopted.
- Compliance analyses determine the actual compliance percentage and discounts the potential savings accordingly.
- NOMAD analyses account for naturally occurring adoption in the market that would occur regardless of utility involvement.
- Attribution analyses determine how much of the energy savings can be directly attributed to the utilities' actions partially based on the research effort, CASE report preparation, and work in the public procedures.
- Allocation analyses distribute resulting energy savings to each utility based on the percentage of statewide sales.

CASE reports and the evaluation model provide much-needed data that encourages utility involvement in building energy codes and have had historical success in the state of California.

A federal EERS would be a promising solution to standardize energy savings, ensure consistent data collection, and advance building energy code adoption. Utilization of utility companies to partially fund and motivate code adoption and compliance could reduce the financial pressure on state and local government agencies. Some features of a federal EERS include, but are not limited to, documenting utility involvement in the codes process, unifying requirements across jurisdictions, and developing a crediting and reporting system that emphasizes compliance and training (Cooper & Wood, 2011).

## Future Work Needed

In order to refine the total potential GHG emissions savings available for current building energy code adoption in the U.S., residential codes must be analyzed in conjunction with commercial codes. In addition, the economic benefit of multiple years under increased compliance must be evaluated in order to demonstrate the importance of the speed of adoption and compliance. A more detailed study on compliance percentages for jurisdictions as compared to the state adopted code would also be helpful to give energy savings as a single number estimate rather than a range. Furthermore, more detailed emissions factors than the annual average factors provided by eGRID should be used to refine the estimate of emission savings. Use of the eGRID factors is an oversimplification since the factors have been shown to change "by time of day and year within a particular region" (Palmer & Walls, 2015). Additional details on this emission savings estimate will increase information for policymakers to use in pursuing improved adoption and compliance nationwide.

Further investigation into utility involvement is also needed. By incentivizing utilities through a federal EERS, this would allow utilities to act in conjunction with the state and local governments and become a means of enforcing building energy codes, thereby relieving some of the financial and personnel strain from the government and transfer enforcement responsibilities to the utilities, which should be motivated by the sound investment proven by the benefit-to-cost ratio of building energy code adoption and enforcement.

# Chapter 5 - Conclusion

Is building energy code adoption and compliance a viable option for GHG emissions reduction? With percent savings below the 1% point, building energy codes do not appear to substantially influence national GHG emissions. However, national GHG emission reduction goals must include economic, political, and social considerations in addition to energy and emissions savings potential. In the long-term, increased building energy code adoption may be the most economical way to achieve emissions savings at a cost-to-savings ratio of 400:1 for the BECP (Livingston et al., 2014). Furthermore, building energy codes are one of the best vehicles driving at least *some* energy savings, even if the savings do not cover the entire GHG emission reduction necessary for the U.S. to achieve national emission reduction goals. Ultimately, no one-size-fits-all solution for achieving national emission reduction goals is currently available or practical. Making substantial reductions in GHG emissions will require long-term changes in policy and attitude. Because energy usage, depletion of natural resources, and the state of the economy are interdependent, achieving national emission reduction goals is not possible without a laundry list of pros and cons. For the long-term health of the U.S. economy and the environment, the argument could be made that several little changes in GHG emissions policy over the next few years would be more conducive to meeting these goals than a few large changes. However, more serious action in GHG emissions policy must begin now. Since enhanced building energy code adoption and compliance immediately contribute to GHG emission reduction, they remain a key part of the solution for reducing GHG emissions, even if they do not constitute entire solution. Overall, adoption and compliance of building energy codes have been shown to benefit the environment, the economy, and global society in general. Historically, the United States has been slow to act on progressive, environmental issues. That inaction is making purely market driven change more difficult. If policy and attitudes do not change soon, what will be the consequences?

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# Appendix A - BECP Adoption and Compliance Assumptions

Understanding the assumptions presented with claims of energy savings is extremely important in order to understand if the energy savings claimed is reasonable or unreasonable. The assumptions in Table A.1 illustrate “less than ideal” adoption times from Livingston et al. (2014).

**Table A.1: Base Case and Immediate Adoption Scenario, Commercial Energy Codes (Reproduced with Permisison from Livingston et al., 2014)**

| | Starting Point | Base case | Immediate Adoption | | | | |
|---|---|---|---|---|---|---|---|
| | Code in Effect in 2013 | | **IECC 2012** | **IECC 2015** | **IECC 2018** | **IECC 2021** | **IECC 2024** |
| Alabama | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Alaska | IECC 2003 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Arizona | IECC 2003 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Arkansas | IECC 2003 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| California | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Colorado | IECC 2006 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Connecticut | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Delaware | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| District of Columbia | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Florida | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Georgia | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Hawaii | IECC 2006 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Idaho | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Illinois | IECC 2012 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Indiana | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Iowa | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Kansas | IECC 2003 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Kentucky | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Louisiana | IECC 2006 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Maine | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Maryland | IECC 2012 | No Change | 2012 | 2016 | 2019 | 2022 | 2025 |
| Massachusetts | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Michigan | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Minnesota | IECC 2006 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Mississippi | IECC 2003 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Missouri | IECC 2003 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Montana | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Nebraska | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Nevada | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| New Hampshire | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| New Jersey | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| New Mexico | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| New York | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| North Carolina | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| North Dakota | IECC 2006 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Ohio | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Oklahoma | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Oregon | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Pennsylvania | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Rhode Island | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| South Carolina | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| South Dakota | IECC 2003 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Tennessee | IECC 2006 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Texas | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Utah | IECC 2006 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Vermont | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Virginia | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Washington | IECC 2012 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| West Virginia | IECC 2009 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Wisconsin | IECC 2006 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |
| Wyoming | IECC 2003 | No Change | 2013 | 2016 | 2019 | 2022 | 2025 |

# Appendix B - Climate Zone Table by County

In calculating the energy savings for each state, establishing the climate zone of each state is important to ensure the proper savings estimates are being used. Since most states have more than one climate zone within the state, a county-by-county method was used to accurately estimate the energy savings in each state. Table B.1 from ASHRAE Standard 90.1-2010 was used to determine the climate zone by county.

**Table B.1: U.S. Climate Zones (Reproduced with Permission from ©ASHRAE, www.ashrae.org. (2010) ASHRAE Standard 90.1-2010)**

| State / County | Zone |
|---|---|
| **Alabama (AL)** | |
| Zone 3a Except | |
| Baldwin | 2A |
| Mobile | 2A |
| **Alaska (AK)** | |
| Zone 7 Except | |
| Bethel (CA) | 8 |
| Dillingham (CA) | 8 |
| Fairbanks North Star | 8 |
| Nome (CA) | 8 |
| North Slope | 8 |
| Northwest Arctic | 8 |
| Southeast Fairbanks (CA) | 8 |
| Wade Hampton (CA) | 8 |
| Yukon-Koyukuk (CA) | 8 |
| **Arizona (AZ)** | |
| Zone 3B Except | |
| La Paz | 2B |
| Maricopa | 2B |
| Pima | 2B |
| Pinal | 2B |
| Yuma | 2B |
| Gila | 4B |
| Yavapai | 4B |
| Apache | 5B |
| Coconino | 5B |
| Navajo | 5B |
| **Arkansas (AR)** | |
| Zone 3A Except | |
| Baxter | 4A |
| Benton | 4A |
| Boone | 4A |
| Carroll | 4A |
| Fulton | 4A |
| Izard | 4A |
| Madison | 4A |
| Marion | 4A |
| Newton | 4A |
| Searcy | 4A |
| Stone | 4A |
| (Arkansas cont.) | |
| Washington | 4A |
| **California (CA)** | |
| Zone 3B Except | |
| Imperial | 2B |
| Alameda | 3C |
| Marin | 3C |
| Mendocino | 3C |
| Monterey | 3C |
| Napa | 3C |
| San Benito | 3C |
| San Francisco | 3C |
| San Luis Obispo | 3C |
| San Mateo | 3C |
| Santa Barbara | 3C |
| Santa Clara | 3C |
| Santa Cruz | 3C |
| Sonoma | 3C |
| Ventura | 3C |
| Amador | 4B |
| Calaveras | 4B |
| Del Norte | 4B |
| El Dorado | 4B |
| Humboldt | 4B |
| Inyo | 4B |
| Lake | 4B |
| Mariposa | 4B |
| Trinity | 4B |
| Tuolumme | 4B |
| Lassen | 5B |
| Modoc | 5B |
| Nevada | 5B |
| Plumas | 5B |
| Sierra | 5B |
| Siskiyou | 5B |
| Alpine | 6B |
| Mono | 6B |
| **Colorado (CO)** | |
| Zone 5B Except | |
| Baca | 4B |
| (Colorado cont.) | |
| Las Animas | 4B |
| Otero | 4B |
| Alamosa | 6B |
| Archuleta | 6B |
| Chaffee | 6B |
| Conejos | 6B |
| Costilla | 6B |
| Custer | 6B |
| Dolores | 6B |
| Eagle | 6B |
| Moffat | 6B |
| Ouray | 6B |
| Rio Blanco | 6B |
| Saguache | 6B |
| San Miguel | 6B |
| Clear Creek | 7 |
| Grand | 7 |
| Gunnison | 7 |
| Hinsdale | 7 |
| Jackson | 7 |
| Lake | 7 |
| Mineral | 7 |
| Park | 7 |
| Pitkin | 7 |
| Rio Grande | 7 |
| Routt | 7 |
| San Juan | 7 |
| Summitt | 7 |
| **Connecticut (CT)** | |
| Zone 5A | |
| **Delaware (DE)** | |
| Zone 4A | |
| **District of Columbia (DC)** | |
| Zone 4A | |
| **Florida (FL)** | |
| Zone 2A Except | |
| Broward | 1A |
| Miami-Dade | 1A |
| Monroe | 1A |
| **Georgia (GA)** | |
| Zone 3A Except | |
| Appling | 2A |
| Atkinson | 2A |
| Bacon | 2A |
| Baker | 2A |
| Berrien | 2A |
| Brantley | 2A |
| Brooks | 2A |
| Bryan | 2A |
| Camden | 2A |
| Charlton | 2A |
| Chatham | 2A |
| Clinch | 2A |
| Colquitt | 2A |
| Cook | 2A |
| Decatur | 2A |
| Echols | 2A |
| Effingham | 2A |
| Evans | 2A |
| Glynn | 2A |
| Grady | 2A |
| Jeff Davis | 2A |
| Lanier | 2A |
| Liberty | 2A |
| Long | 2A |
| Lowndes | 2A |
| McIntosh | 2A |
| Miller | 2A |
| Mitchell | 2A |
| Pierce | 2A |
| Seminole | 2A |
| Tattnall | 2A |
| Thomas | 2A |
| Toombs | 2A |
| Ware | 2A |
| Wayne | 2A |
| Banks | 4A |
| Catoosa | 4A |
| Chattooga | 4A |

| State<br>County | Zone |
|---|---|
| (Georgia cont.) | |
| Dade | 4A |
| Dawson | 4A |
| Fannin | 4A |
| Floyd | 4A |
| Franklin | 4A |
| Gilmer | 4A |
| Gordon | 4A |
| Habersham | 4A |
| Hall | 4A |
| Lumpkin | 4A |
| Murray | 4A |
| Pickens | 4A |
| Rabun | 4A |
| Stephens | 4A |
| Towns | 4A |
| Union | 4A |
| Walker | 4A |
| White | 4A |
| Whitfield | 4A |
| Hawaii (HI) | |
| Zone 1A | |
| Idaho (ID) | |
| Zone 6B Except | |
| Ada | 5B |
| Benewah | 5B |
| Canyon | 5B |
| Cassia | 5B |
| Clearwater | 5B |
| Elmore | 5B |
| Gem | 5B |
| Gooding | 5B |
| Idaho | 5B |
| Jerome | 5B |
| Kootenai | 5B |
| Latah | 5B |
| Lewis | 5B |
| Lincoln | 5B |
| Minidoka | 5B |
| Nez Perce | 5B |
| Owyhee | 5B |
| (Idaho cont.) | |
| Payette | 5B |
| Power | 5B |
| Shoshone | 5B |
| Twin Falls | 5B |
| Washington | 5B |
| Illinois (IL) | |
| Zone 5A Except | |
| Alexander | 4A |
| Bond | 4A |
| Christian | 4A |
| Clay | 4A |
| Clinton | 4A |
| Crawford | 4A |
| Edwards | 4A |
| Effingham | 4A |
| Fayette | 4A |
| Franklin | 4A |
| Gallatin | 4A |
| Hamilton | 4A |
| Hardin | 4A |
| Jackson | 4A |
| Jasper | 4A |
| Jefferson | 4A |
| Johnson | 4A |
| Lawrence | 4A |
| Macoupin | 4A |
| Madison | 4A |
| Monroe | 4A |
| Montgomery | 4A |
| Perry | 4A |
| Pope | 4A |
| Pulaski | 4A |
| Randolph | 4A |
| Richland | 4A |
| Saline | 4A |
| Shelby | 4A |
| St. Clair | 4A |
| Union | 4A |
| Wabash | 4A |
| Washington | 4A |
| (Illinois cont.) | |
| Wayne | 4A |
| White | 4A |
| Williamson | 4A |
| Indiana (IN) | |
| Zone 5A Except | |
| Brown | 4A |
| Clark | 4A |
| Crawford | 4A |
| Daviess | 4A |
| Dearborn | 4A |
| Dubois | 4A |
| Floyd | 4A |
| Gibson | 4A |
| Greene | 4A |
| Harrison | 4A |
| Jackson | 4A |
| Jefferson | 4A |
| Jennings | 4A |
| Knox | 4A |
| Lawrence | 4A |
| Martin | 4A |
| Monroe | 4A |
| Ohio | 4A |
| Orange | 4A |
| Perry | 4A |
| Pike | 4A |
| Posey | 4A |
| Ripley | 4A |
| Scott | 4A |
| Spencer | 4A |
| Sullivan | 4A |
| Switzerland | 4A |
| Vanderburgh | 4A |
| Warrick | 4A |
| Washington | 4A |
| Iowa (IA) | |
| Zone 5A Except | |
| Allamakee | 6A |
| Black Hawk | 6A |
| Bremer | 6A |
| (Iowa cont.) | |
| Buchanan | 6A |
| Buena Vista | 6A |
| Butler | 6A |
| Calhoun | 6A |
| Cerro Gordo | 6A |
| Cherokee | 6A |
| Chickasaw | 6A |
| Clay | 6A |
| Clayton | 6A |
| Delaware | 6A |
| Dickinson | 6A |
| Emmet | 6A |
| Fayette | 6A |
| Floyd | 6A |
| Franklin | 6A |
| Grundy | 6A |
| Hamilton | 6A |
| Hancock | 6A |
| Hardin | 6A |
| Howard | 6A |
| Humboldt | 6A |
| Ida | 6A |
| Kossuth | 6A |
| Lyon | 6A |
| Mitchell | 6A |
| O'Brien | 6A |
| Osceola | 6A |
| Palo Alto | 6A |
| Plymouth | 6A |
| Pocahontas | 6A |
| Sac | 6A |
| Sioux | 6A |
| Webster | 6A |
| Winnebago | 6A |
| Worth | 6A |
| Wright | 6A |
| Kansas (KS) | |
| Zone 4A Except | |
| Cheyenne | 5A |
| Cloud | 5A |

| State<br>County | Zone |
|---|---|
| (Kansas cont.) | |
| Decatur | 5A |
| Ellis | 5A |
| Gove | 5A |
| Graham | 5A |
| Greeley | 5A |
| Hamilton | 5A |
| Jewell | 5A |
| Lane | 5A |
| Logan | 5A |
| Mitchell | 5A |
| Ness | 5A |
| Norton | 5A |
| Osborne | 5A |
| Phillips | 5A |
| Rawlins | 5A |
| Republic | 5A |
| Rooks | 5A |
| Scott | 5A |
| Sheridan | 5A |
| Sherman | 5A |
| Smith | 5A |
| Thomas | 5A |
| Trego | 5A |
| Wallace | 5A |
| Wichita | 5A |
| Kentucky (KY) | |
| Zone 4A | |
| Louisiana (LA) | |
| Zone 2A Except | |
| Bienville | 3A |
| Bossier | 3A |
| Caddo | 3A |
| Caldwell | 3A |
| Catahoula | 3A |
| Claiborne | 3A |
| Concordia | 3A |
| De Soto | 3A |
| East Carroll | 3A |
| Franklin | 3A |
| Grant | 3A |
| (Louisiana cont.) | |
| Jackson | 3A |
| La Salle | 3A |
| Lincoln | 3A |
| Madison | 3A |
| Morehouse | 3A |
| Natchitoches | 3A |
| Ouachita | 3A |
| Red River | 3A |
| Richland | 3A |
| Sabine | 3A |
| Tensas | 3A |
| Union | 3A |
| Vernon | 3A |
| Webster | 3A |
| West Carroll | 3A |
| Winn | 3A |
| Maine (ME) | |
| Zone 6A Except | |
| Aroostook | 7 |
| Maryland (MD) | |
| Zone 4A Except | |
| Garrett | 5A |
| Massachusetts (MA) | |
| Zone 5 | |
| Michigan (MI) | |
| Zone 5A Except | |
| Alcona | 6A |
| Alger | 6A |
| Alpena | 6A |
| Antrim | 6A |
| Arenac | 6A |
| Benzie | 6A |
| Charlevoix | 6A |
| Cheboygan | 6A |
| Clare | 6A |
| Crawford | 6A |
| Delta | 6A |
| Dickinson | 6A |
| Emmet | 6A |
| Gladwin | 6A |
| (Michigan cont.) | |
| Grand Traverse | 6A |
| Huron | 6A |
| Iosco | 6A |
| Isabella | 6A |
| Kalkaska | 6A |
| Lake | 6A |
| Leelanau | 6A |
| Manistee | 6A |
| Marquette | 6A |
| Mason | 6A |
| Mecosta | 6A |
| Menominee | 6A |
| Missaukee | 6A |
| Montmorency | 6A |
| Newaygo | 6A |
| Oceana | 6A |
| Ogemaw | 6A |
| Osceola | 6A |
| Oscoda | 6A |
| Otsego | 6A |
| Presque Isle | 6A |
| Roscommon | 6A |
| Sanilac | 6A |
| Wexford | 6A |
| Baraga | 7 |
| Chippewa | 7 |
| Gogebic | 7 |
| Houghton | 7 |
| Iron | 7 |
| Keweenaw | 7 |
| Luce | 7 |
| Mackinac | 7 |
| Ontonagon | 7 |
| Schoolcraft | 7 |
| Minnesota (MN) | |
| Zone 6A Except | |
| Aitkin | 7 |
| Becker | 7 |
| Beltrami | 7 |
| Carlton | 7 |
| (Minnesota cont.) | |
| Cass | 7 |
| Clay | 7 |
| Clearwater | 7 |
| Cook | 7 |
| Crow Wing | 7 |
| Grant | 7 |
| Hubbard | 7 |
| Itasca | 7 |
| Kanabec | 7 |
| Kittson | 7 |
| Koochiching | 7 |
| Lake | 7 |
| Lake of the Woods | 7 |
| Mahnomen | 7 |
| Marshall | 7 |
| Mille Lacs | 7 |
| Norman | 7 |
| Otter Trail | 7 |
| Pennington | 7 |
| Pine | 7 |
| Polk | 7 |
| Red Lake | 7 |
| Roseau | 7 |
| St. Louis | 7 |
| Wadena | 7 |
| Wilkin | 7 |
| Mississippi (MS) | |
| Zone 3A Except | |
| Hancock | 2A |
| Harrison | 2A |
| Jackson | 2A |
| Pearl River | 2A |
| Stone | 2A |
| Missouri (MO) | |
| Zone 4A Except | |
| Adair | 5A |
| Andrew | 5A |
| Atchison | 5A |
| Buchanan | 5A |
| Caldwell | 5A |

| State County | Zone |
|---|---|
| (Missouri cont.) | |
| Chariton | 5A |
| Clark | 5A |
| Clinton | 5A |
| Daviess | 5A |
| Gentry | 5A |
| Grundy | 5A |
| Harrison | 5A |
| Holt | 5A |
| Knox | 5A |
| Lewis | 5A |
| Linn | 5A |
| Livingston | 5A |
| Macon | 5A |
| Marion | 5A |
| Mercer | 5A |
| Nodaway | 5A |
| Pike | 5A |
| Putnam | 5A |
| Ralls | 5A |
| Schuyler | 5A |
| Scotland | 5A |
| Shelby | 5A |
| Sullivan | 5A |
| Worth | 5A |
| Montana (MT) | |
| Zone 6B | |
| Nebraska (NE) | |
| Zone 5A | |
| Nevada (NV) | |
| Zone 5B Except | |
| Clark | 3B |
| New Hampshire (NH) | |
| Zone 6A Except | |
| Cheshire | 5A |
| Hillsborough | 5A |
| Rockingham | 5A |
| Strafford | 5A |
| New Jersey (NJ) | |
| Zone 4A Except | |
| Bergen | 5A |
| (New Jersey cont.) | |
| Hunterdon | 5A |
| Mercer | 5A |
| Morris | 5A |
| Passaic | 5A |
| Somerset | 5A |
| Sussex | 5A |
| Warren | 5A |
| New Mexico (NM) | |
| Zone 5B Except | |
| Chaves | 3B |
| Dona Ana | 3B |
| Eddy | 3B |
| Hidalgo | 3B |
| Lea | 3B |
| Luna | 3B |
| Otero | 3B |
| Bernalillo | 4B |
| Curry | 4B |
| DeBaca | 4B |
| Grant | 4B |
| Guadalupe | 4B |
| Lincoln | 4B |
| Quay | 4B |
| Roosevelt | 4B |
| Sierra | 4B |
| Socorro | 4B |
| Union | 4B |
| Valencia | 4B |
| New York (NY) | |
| Zone 5A Except | |
| Bronx | 4A |
| Kings | 4A |
| Nassau | 4A |
| New York | 4A |
| Queens | 4A |
| Richmond | 4A |
| Suffolk | 4A |
| Westchester | 4A |
| Allegany | 6A |
| Broome | 6A |
| (New York cont.) | |
| Cattaraugus | 6A |
| Chenango | 6A |
| Clinton | 6A |
| Delaware | 6A |
| Essex | 6A |
| Franklin | 6A |
| Fulton | 6A |
| Hamilton | 6A |
| Herkimer | 6A |
| Jefferson | 6A |
| Lewis | 6A |
| Madison | 6A |
| Montgomery | 6A |
| Oneida | 6A |
| Otsego | 6A |
| Schoharie | 6A |
| Schuyler | 6A |
| St. Lawrence | 6A |
| Steuben | 6A |
| Sullivan | 6A |
| Tompkins | 6A |
| Ulster | 6A |
| Warren | 6A |
| Wyoming | 6A |
| North Carolina (NC) | |
| Zone 4A Except | |
| Anson | 3A |
| Beaufort | 3A |
| Bladen | 3A |
| Brunswick | 3A |
| Cabarrus | 3A |
| Camden | 3A |
| Carteret | 3A |
| Chowan | 3A |
| Columbus | 3A |
| Craven | 3A |
| Cumberland | 3A |
| Currituck | 3A |
| Dare | 3A |
| Davidson | 3A |
| (North Carolina cont.) | |
| Duplin | 3A |
| Edgecombe | 3A |
| Gaston | 3A |
| Greene | 3A |
| Hoke | 3A |
| Hyde | 3A |
| Johnston | 3A |
| Jones | 3A |
| Lenoir | 3A |
| Martin | 3A |
| Mecklenberg | 3A |
| Montgomery | 3A |
| Moore | 3A |
| New Hanover | 3A |
| Onslow | 3A |
| Pamlico | 3A |
| Pasquotank | 3A |
| Pender | 3A |
| Perquimans | 3A |
| Pitt | 3A |
| Randolph | 3A |
| Richmond | 3A |
| Robeson | 3A |
| Rowan | 3A |
| Sampson | 3A |
| Scotland | 3A |
| Stanly | 3A |
| Tyrrell | 3A |
| Union | 3A |
| Washington | 3A |
| Wayne | 3A |
| Wilson | 3A |
| Alleghany | 5A |
| Ashe | 5A |
| Avery | 5A |
| Mitchell | 5A |
| Watauga | 5A |
| Yancey | 5A |
| North Dakota (ND) | |
| Zone 7 Except | |

| State<br>County | Zone | State<br>County | Zone | State<br>County | Zone | State<br>County | Zone |
|---|---|---|---|---|---|---|---|
| (North Dakota cont.) | | Oregon (OR) | | (South Dakota cont.) | | (Texas cont.) | |
| Adams | 6A | Zone 4C Except | | Jackson | 5A | Calhoun | 2A |
| Billings | 6A | Baker | 5B | Mellette | 5A | Cameron | 2A |
| Bowman | 6A | Crook | 5B | Todd | 5A | Chambers | 2A |
| Burleigh | 6A | Deschutes | 5B | Tripp | 5A | Cherokee | 2A |
| Dickey | 6A | Gilliam | 5B | Union | 5A | Colorado | 2A |
| Dunn | 6A | Grant | 5B | Yankton | 5A | Comal | 2A |
| Emmons | 6A | Harney | 5B | Tennessee (TN) | | Coryell | 2A |
| Golden Valley | 6A | Hood River | 5B | Zone 4A Except | | DeWitt | 2A |
| Grant | 6A | Jefferson | 5B | Chester | 3A | Dimmit | 2B |
| Hettinger | 6A | Klamath | 5B | Crockett | 3A | Duval | 2A |
| LaMoure | 6A | Lake | 5B | Dyer | 3A | Edwards | 2B |
| Logan | 6A | Malheur | 5B | Fayette | 3A | Falls | 2A |
| McIntosh | 6A | Morrow | 5B | Hardeman | 3A | Fayette | 2A |
| McKenzie | 6A | Sherman | 5B | Hardin | 3A | Fort Bend | 2A |
| Mercer | 6A | Umatilla | 5B | Haywood | 3A | Freestone | 2A |
| Morton | 6A | Union | 5B | Henderson | 3A | Frio | 2B |
| Oliver | 6A | Wallowa | 5B | Lake | 3A | Galveston | 2A |
| Ransom | 6A | Wasco | 5B | Lauderdale | 3A | Goliad | 2A |
| Richland | 6A | Wheeler | 5B | Madison | 3A | Gonzales | 2A |
| Sargent | 6A | Pennsylvania (PA) | | McNairy | 3A | Grimes | 2A |
| Sioux | 6A | Zone 5A Except | | Shelby | 3A | Guadalupe | 2A |
| Slope | 6A | Bucks | 4A | Tipton | 3A | Hardin | 2A |
| Stark | 6A | Chester | 4A | Texas (TX) | | Harris | 2A |
| Ohio (OH) | | Delaware | 4A | Zone 3A Except | | Hays | 2A |
| Zone 5A Except | | Montgomery | 4A | Anderson | 2A | Hidalgo | 2A |
| Adams | 4A | Philadelphia | 4A | Angelina | 2A | Hill | 2A |
| Brown | 4A | York | 4A | Aransas | 2A | Houston | 2A |
| Clermont | 4A | Rhode Island (RI) | | Atascosa | 2A | Jackson | 2A |
| Gallia | 4A | Zone 5A | | Austin | 2A | Jasper | 2A |
| Hamilton | 4A | South Carolina (SC) | | Bandera | 2B | Jefferson | 2A |
| Lawrence | 4A | Zone 3A | | Bastrop | 2A | Jim Hogg | 2A |
| Pike | 4A | South Dakota (SD) | | Bee | 2A | Jim Wells | 2A |
| Scioto | 4A | Zone 6A Except | | Bell | 2A | Karnes | 2A |
| Washington | 4A | Bennett | 5A | Bexar | 2A | Kenedy | 2A |
| Oklahoma (OK) | | Bon Homme | 5A | Bosque | 2A | Kinney | 2B |
| Zone 3A Except | | Charles Mix | 5A | Brazoria | 2A | Kleberg | 2A |
| Beaver | 4A | Clay | 5A | Brazos | 2A | La Salle | 2B |
| Cimarron | 4A | Douglas | 5A | Brooks | 2A | Lavaca | 2A |
| Texas | 4A | Gregory | 5A | Burleson | 2A | Lee | 2A |
| | | Hutchinson | 5A | Caldwell | 2A | Leon | 2A |

| State County | Zone | State County | Zone | State County | Zone | State County | Zone |
|---|---|---|---|---|---|---|---|
| (Texas cont.) | | (Texas cont.) | | (Texas cont.) | | (Texas cont.) | |
| Liberty | 2A | Brewster | 3B | Mason | 3B | Hansford | 4B |
| Limestone | 2A | Callahan | 3B | McCulloch | 3B | Hartley | 4B |
| Live Oak | 2A | Childress | 3B | Menard | 3B | Hockley | 4B |
| Madison | 2A | Coke | 3B | Midland | 3B | Hutchinson | 4B |
| Matagorda | 2A | Coleman | 3B | Mitchell | 3B | Lamb | 4B |
| Maverick | 2B | Concho | 3B | Motley | 3B | Lipscomb | 4B |
| McLennan | 2A | Cottle | 3B | Nolan | 3B | Moore | 4B |
| McMullen | 2A | Crane | 3B | Pecos | 3B | Ochiltree | 4B |
| Medina | 2B | Crockett | 3B | Presidio | 3B | Oldham | 4B |
| Milam | 2A | Crosby | 3B | Reagan | 3B | Parmer | 4B |
| Montgomery | 2A | Culberson | 3B | Reeves | 3B | Potter | 4B |
| Newton | 2A | Dawson | 3B | Runnels | 3B | Randall | 4B |
| Nueces | 2A | Dickens | 3B | Schleicher | 3B | Roberts | 4B |
| Orange | 2A | Ector | 3B | Scurry | 3B | Sherman | 4B |
| Polk | 2A | El Paso | 3B | Shackelford | 3B | Swisher | 4B |
| Real | 2B | Fisher | 3B | Sterling | 3B | Yoakum | 4B |
| Refugio | 2A | Foard | 3B | Stonewall | 3B | Utah (UT) | |
| Robertson | 2A | Gaines | 3B | Sutton | 3B | Zone 5B Except | |
| San Jacinto | 2A | Garza | 3B | Taylor | 3B | Washington | 3B |
| San Patricio | 2A | Glasscock | 3B | Terrell | 3B | Box Elder | 6B |
| Starr | 2A | Hackell | 3B | Terry | 3B | Cache | 6B |
| Travis | 2A | Hall | 3B | Throckmorton | 3B | Carbon | 6B |
| Trinity | 2A | Hardeman | 3B | Tom Green | 3B | Daggett | 6B |
| Tyler | 2A | Haskell | 3B | Upton | 3B | Duchesne | 6B |
| Uvalde | 2B | Hemphill | 3B | Ward | 3B | Morgan | 6B |
| Val Verde | 2B | Howard | 3B | Wheeler | 3B | Rich | 6B |
| Victoria | 2A | Hudspeth | 3B | Wilbarger | 3B | Summit | 6B |
| Walker | 2A | Irion | 3B | Winkler | 3B | Uintah | 6B |
| Waller | 2A | Jeff Davis | 3B | Armstrong | 4B | Wasatch | 6B |
| Washington | 2A | Jones | 3B | Bailey | 4B | Vermont (VT) | |
| Webb | 2B | Kendall | 3B | Briscoe | 4B | Zone 6A | |
| Wharton | 2A | Kent | 3B | Carson | 4B | Virginia (VA) | |
| Willacy | 2A | Kerr | 3B | Castro | 4B | Zone 4A | |
| Williamson | 2A | King | 3B | Cochran | 4B | Washington (WA) | |
| Wilson | 2A | Knox | 3B | Dallam | 4B | Zone 5B Except | |
| Zapata | 2B | Lipscomb | 3B | Deaf Smith | 4B | Clallam | 4C |
| Zavala | 2B | Loving | 3B | Donley | 4B | Clark | 4C |
| Andrews | 3B | Lubbock | 3B | Floyd | 4B | Cowlitz | 4C |
| Baylor | 3B | Lynn | 3B | Gray | 4B | Grays Harbor | 4C |
| Borden | 3B | Martin | 3B | Hale | 4B | Jefferson | 4C |

| State<br>County | Zone |
|---|---|
| (Washington cont.) | |
| King | 4C |
| Kitsap | 4C |
| Lewis | 4C |
| Mason | 4C |
| Pacific | 4C |
| Pierce | 4C |
| Skagit | 4C |
| Snohomisg | 4C |
| Thurston | 4C |
| Wahkiakum | 4C |
| Whatcom | 4C |
| Ferry | 6B |
| Okanogan | 6B |
| Pend Oreille | 6B |
| Stevens | 6B |
| West Virginia (WV) | |
| Zone 5A Except | |
| Berkeley | 4A |
| Boone | 4A |
| Braxton | 4A |
| Cabell | 4A |
| Calhoun | 4A |
| Clay | 4A |
| Gilmer | 4A |
| Jackson | 4A |
| Jefferson | 4A |
| Kanawha | 4A |
| Lincoln | 4A |
| Logan | 4A |
| Mason | 4A |
| McDowell | 4A |
| Mercer | 4A |
| Mingo | 4A |
| Monroe | 4A |
| Morgan | 4A |
| Pleasants | 4A |
| Putnam | 4A |
| Ritchie | 4A |
| Roane | 4A |
| Tyler | 4A |

| State<br>County | Zone |
|---|---|
| (West Virginia cont.) | |
| Wayne | 4A |
| Wirt | 4A |
| Wood | 4A |
| Wyoming | 4A |
| Wisconsin (WI) | |
| Zone 6A Except | |
| Ashland | 7A |
| Bayfield | 7A |
| Burnett | 7A |
| Douglas | 7A |
| Florence | 7A |
| Forest | 7A |
| Iron | 7A |
| Langlade | 7A |
| Lincoln | 7A |
| Oneida | 7A |
| Price | 7A |
| Sawyer | 7A |
| Taylor | 7A |
| Vilas | 7A |
| Washburn | 7A |
| Wyoming (WY) | |
| Zone 6B Except | |
| Goshen | 5B |
| Platte | 5B |
| Lincoln | 7B |
| Sublette | 7B |
| Teton | 7B |
| Puerto Rico (PR) | |
| Zone 1A Except | |
| Barranquitas 2 SSW | 2B |
| Cayey 1 E | 2B |
| Pacific Islands (PI) | |
| Zone 1A Except | |
| Midway Sand Island | 2B |
| Virgin Islands (VI) | |
| Zone 1A | |

# Appendix C - CBECS and ASHRAE Prototype Buildings

The most accurate and recent square footage data was compiled by the 2003-2007 CBECS. However, most energy modeling data utilizes ASHRAE prototypes. Table C.1 shows the weights of the ASHRAE prototypes based on the CBECS building types.

**Table C.1: Weights of ASHRAE Prototypes in Reference to CBECS Prototypes (Reproduced with Permission from Gilbraith et al., 2014)**

| CBECS Bldg. Type | EnergyPlus Bldg. Prototype | Allocation (% of CBECS) | % of Total Floor Space |
|---|---|---|---|
| Office | Lg. Office | 22% | 3% |
| | Med. Office | 40% | 5% |
| | Sm. Office | 37% | 4% |
| Retail | Retail | 73% | 12% |
| | Strip mall | 27% | 5% |
| School | Primary School | 33% | 4% |
| | Secondary School | 67% | 8% |
| Healthcare | Hospital | 44% | 3% |
| | Outpatient Healthcare | 56% | 3% |
| Restaurant | Sit-down Restaurant | 53% | 1% |
| | Fast-food | 47% | 0% |
| Hotel | Lg. Hotel | 74% | 4% |
| | Sm. Hotel | 26% | 1% |
| Warehouse | Warehouse | 100% | 13% |
| Apartment | High-rise Apartment | 55% | 7% |
| | Mid-rise Apartment | 45% | 6% |
| *Public Assembly* | *No Prototype* | | *5%* |
| *No CBECS Type* | | | *15%* |

# Appendix D - State-by-State Energy Savings Methodology and Results

First, electricity and natural gas EUI values for ASHRAE Standard 90.1-2004 through ASHRAE Standard 90.1-2013 were gathered for each prototype building across all climate zones. Next, the square footage was gathered for each prototype building in each state according to CBECS. These square footages were then converted to ASHRAE prototype buildings via the percentages shown in Appendix C. The EUI values were then multiplied by corresponding square footage to get a total energy usage in BTUs for each energy code. The equations used are shown below.

$$\boldsymbol{E_{yy-xx-zz-e} = EUI_{yy-xx-zz-e} * SF_{yy-zz}}$$

**Equation 1: State Electricity Prototype Building Energy Usage in Specific Code Year (BTUs)**

where,

$E_{yy-xx-zz-e}$= Energy Usage in BTU for electricity in a zz prototype building in xx adopted code year for yy state

$EUI_{yy-xx-zz-e}$= Energy Usage Intensity in BTU/ft$^2$ for electricity in a zz prototype building in xx adopted code year for yy state

$SF_{yy-zz}$= Square footage for zz prototype building in yy state

and,

$$\boldsymbol{E_{yy-xx-zz-ng} = EUI_{yy-xx-zz-ng} * SF_{yy-zz}}$$

**Equation 2: State Natural Gas Prototype Building Energy Usage in Specific Code Year (BTUs)**

where,

$E_{yy-xx-zz-ng}$= Energy Usage in BTU for natural gas in a zz prototype building in xx adopted code year for yy state

$EUI_{yy-xx-zz-ng}$= Energy Usage Intensity in BTU/ft$^2$ for natural gas in a zz prototype building in xx adopted code year for yy state

$SF_{yy-zz}$= Square footage for zz prototype building in yy state

The energy savings through complying and enforcing ASHRAE Standard 90.1-2013 for each state was determined by subtracting the 90.1-2013 energy usage from the current state adopted energy code. The equations used for these calculations are shown below.

$$\boldsymbol{ES_{yy-zz-e} = E_{yy-xx-zz-e} - E_{yy-13-zz-e}}$$

**Equation 3: State Electricity Prototype Building Energy Savings (BTUs)**

where,

$ES_{yy-zz-e}$= Energy Savings in BTU for electricity in a zz prototype building in yy state

$E_{yy-13-zz-e}$= Energy Usage in BTU for electricity in a zz prototype building following ASHRAE Standard 90.1-2013 in yy state

$E_{xx-zz-e}$= Energy Usage in BTU for electricity in a zz prototype building in xx adopted code year in yy state

and,

$$\boldsymbol{ES_{yy-zz-ng} = E_{yy-xx-zz-ng} - E_{yy-13-zz-ng}}$$

**Equation 4: State Electricity Prototype Building Energy Savings (BTUs)**

where,

$ES_{yy-zz-ng}$= Energy Savings in BTU for natural gas in a zz prototype building in yy state

$E_{yy-13-zz-ng}$= Energy Usage in BTU for natural gas in a zz prototype building following ASHRAE Standard 90.1-2013 in yy state

$E_{yy-xx-zz-ng}$= Energy Usage in BTU for natural gas in a zz prototype building in xx adopted code year in yy state

If the state had no energy code, the ASHRAE Standard 90.1-2004 values were used since this code is a good approximation of current unrestricted construction techniques in those states based on the lag discussed by Livingston et al. (2014) in Chapter 3. If the state was currently adopting ASHRAE Standard 90.1-2013, no savings were accounted for. Additionally, a compliance rate ranging from a worst-case scenario of 25% to a best-case scenario of 75% was used to take differing compliance rates across the country into account. As a result, a range of energy savings in BTU for natural gas and electricity through complying with ASHRAE Standard 90.1-2013 was determined for each state across the country according to the following equations.

$$\boldsymbol{ES_{yy-e}} = \left[\sum \boldsymbol{ES_{yy-zz-e}}\right](\boldsymbol{CR})(\boldsymbol{EL})$$

**Equation 5: State Electricity Energy Savings (BTUs)**

where,

$ES_{yy-e}$= Energy Savings for electricity in BTU for yy state

$ES_{yy-zz-e}$= Energy Savings for electricity in BTU for a zz prototype building in yy state

$CR$ = Compliance Rate, either 0.25 or 0.75

$EL$ = Energy Loss factor for non-compliant buildings, 0.85 is used

and,

$$\boldsymbol{ES_{yy-ng}} = \left[\sum \boldsymbol{ES_{yy-zz-ng}}\right](\boldsymbol{CR})(\boldsymbol{EL})$$

**Equation 6: State Natural Gas Energy Savings (BTUs)**

where,

$ES_{yy-ng}$= Energy Savings for natural gas in BTU for yy state

$ES_{yy-zz-ng}$= Energy Savings for natural gas in BTU in zz prototype building in yy state

$CR$ = Compliance Rate, either 0.25 or 0.75

$EL$ = Energy Loss factor for non-compliant buildings, 0.85 is used

After the savings for each state is found, the savings for the whole country is found according to the equations below.

$$\boldsymbol{ES_{e}} = \left[\sum \boldsymbol{ES_{yy-e}}\right]$$

**Equation 7: National Electricity Energy Savings (BTUs)**

where,

$ES_{e}$= Energy Savings for electricity in BTU for the country

$ES_{yy-zz-e}$= Energy Savings for electricity in BTU for yy state and,

$$ES_{ng} = \left[\sum ES_{yy-ng}\right]$$

**Equation 8: National Natural Gas Energy Savings (BTUs)**

where,

$ES_{ng}$= Energy Savings for electricity in BTU for the country

$ES_{yy-ng}$= Energy Savings for natural gas in BTU for yy state

The state-by-state results for these calculations are shown in Table D.1 and Table D.2.

**Table D.1: State-by-State Annual Energy Savings for Electricity**

| Electricity | | | |
|---|---|---|---|
| | | $ES_{yy-e}$ (Tbtu) | |
| State Abbreviation | Current Code Adopted | Low Case | High Case |
| AK | None | 0.03 | 0.08 |
| AL | 90.1-2007 | 0.22 | 0.67 |
| AR | 90.1-2007 | 0.13 | 0.39 |
| AZ | None | 0.48 | 1.44 |
| CA | 90.1-2010 | 0.01 | 0.03 |
| CO | None | 0.30 | 0.91 |
| CT | 90.1-2007 | 0.11 | 0.32 |
| DC | 90.1-2010 | 0.01 | 0.04 |
| DE | 90.1-2010 | 0.01 | 0.02 |
| FL | 90.1-2010 | 0.50 | 1.49 |
| GA | 90.1-2007 | 0.46 | 1.38 |
| HI | 90.1-2007 | 0.04 | 0.12 |
| IA | 90.1-2010 | 0.03 | 0.10 |
| ID | 90.1-2010 | 0.02 | 0.07 |
| IL | 90.1-2010 | 0.14 | 0.41 |
| IN | 90.1-2007 | 0.30 | 0.91 |
| KS | None | 0.13 | 0.38 |
| KY | 90.1-2010 | 0.05 | 0.14 |
| LA | 90.1-2007 | 0.18 | 0.53 |
| MA | 90.1-2010 | 0.05 | 0.16 |
| MD | 90.1-2013 | 0.00 | 0.00 |
| ME | None | 0.05 | 0.14 |
| MI | 90.1-2007 | 0.25 | 0.75 |

| | | | |
|---|---|---|---|
| MN | 90.1-2010 | 0.05 | 0.15 |
| MO | None | 0.24 | 0.73 |
| MS | 90.1-2010 | 0.03 | 0.09 |
| MT | 90.1-2010 | 0.01 | 0.02 |
| NC | 90.1-2007 | 0.40 | 1.19 |
| ND | None | 0.03 | 0.08 |
| NE | 90.1-2007 | 0.08 | 0.24 |
| NH | 90.1-2007 | 0.05 | 0.14 |
| NJ | 90.1-2007 | 0.24 | 0.73 |
| NM | 90.1-2007 | 0.07 | 0.22 |
| NV | 90.1-2010 | 0.08 | 0.24 |
| NY | 90.1-2010 | 0.13 | 0.39 |
| OH | 90.1-2007 | 0.44 | 1.33 |
| OK | None | 0.18 | 0.55 |
| OR | 90.1-2010 | 0.04 | 0.12 |
| PA | 90.1-2007 | 0.37 | 1.10 |
| RI | 90.1-2010 | 0.01 | 0.03 |
| SC | 90.1-2007 | 0.25 | 0.76 |
| SD | None | 0.03 | 0.09 |
| TN | None | 0.33 | 0.98 |
| TX | 90.1-2007 | 1.37 | 4.11 |
| UT | 90.1-2010 | 0.04 | 0.13 |
| VA | 90.1-2010 | 0.09 | 0.28 |
| VT | 90.1-2013 | 0.00 | 0.00 |
| WA | 90.1-2010 | 0.08 | 0.23 |
| WI | 90.1-2007 | 0.19 | 0.57 |
| WV | 90.1-2007 | 0.05 | 0.14 |
| WY | None | 0.02 | 0.06 |
| | $\boldsymbol{ES_e}$ : | **8.40** | **25.20** |

**Table D.2: State-by-State Annual Energy Savings for Natural Gas**

| Natural Gas | | | |
|---|---|---|---|
| State Abbreviation | Current Code Adopted | $\boldsymbol{ES_{yy-ng}}$ (Tbtu) | |
| | | Low Case | High Case |
| AK | None | 0.013 | 0.038 |
| AL | 90.1-2007 | 0.016 | 0.048 |
| AR | 90.1-2007 | 0.011 | 0.033 |

| | | | |
|---|---|---|---|
| AZ | None | 0.025 | 0.076 |
| CA | 90.1-2010 | 0.002 | 0.007 |
| CO | None | 0.063 | 0.188 |
| CT | 90.1-2007 | 0.024 | 0.073 |
| DC | 90.1-2010 | 0.000 | 0.001 |
| DE | 90.1-2010 | 0.000 | 0.001 |
| FL | 90.1-2010 | 0.008 | 0.023 |
| GA | 90.1-2007 | 0.036 | 0.109 |
| HI | 90.1-2007 | 0.001 | 0.002 |
| IA | 90.1-2010 | 0.003 | 0.009 |
| ID | 90.1-2010 | 0.002 | 0.006 |
| IL | 90.1-2010 | 0.015 | 0.044 |
| IN | 90.1-2007 | 0.056 | 0.168 |
| KS | None | 0.024 | 0.073 |
| KY | 90.1-2010 | 0.003 | 0.008 |
| LA | 90.1-2007 | 0.011 | 0.033 |
| MA | 90.1-2010 | 0.005 | 0.016 |
| MD | 90.1-2013 | 0.000 | 0.000 |
| ME | None | 0.016 | 0.049 |
| MI | 90.1-2007 | 0.062 | 0.187 |
| MN | 90.1-2010 | 0.009 | 0.027 |
| MO | None | 0.051 | 0.152 |
| MS | 90.1-2010 | 0.000 | 0.001 |
| MT | 90.1-2010 | 0.001 | 0.004 |
| NC | 90.1-2007 | 0.044 | 0.132 |
| ND | None | 0.010 | 0.030 |
| NE | 90.1-2007 | 0.017 | 0.051 |
| NH | 90.1-2007 | 0.012 | 0.036 |
| NJ | 90.1-2007 | 0.046 | 0.137 |
| NM | 90.1-2007 | 0.004 | 0.012 |
| NV | 90.1-2010 | 0.013 | 0.040 |
| NY | 90.1-2010 | 0.014 | 0.042 |
| OH | 90.1-2007 | 0.084 | 0.251 |
| OK | None | 0.018 | 0.054 |
| OR | 90.1-2010 | 0.002 | 0.005 |
| PA | 90.1-2007 | 0.077 | 0.232 |
| RI | 90.1-2010 | 0.001 | 0.002 |
| SC | 90.1-2007 | 0.017 | 0.051 |
| SD | None | 0.009 | 0.028 |
| TN | None | 0.058 | 0.173 |
| TX | 90.1-2007 | 0.059 | 0.176 |
| UT | 90.1-2010 | 0.003 | 0.008 |

| | | | |
|---|---|---|---|
| VA | 90.1-2010 | 0.004 | 0.013 |
| VT | 90.1-2013 | 0.000 | 0.000 |
| WA | 90.1-2010 | 0.004 | 0.012 |
| WI | 90.1-2007 | 0.055 | 0.166 |
| WV | 90.1-2007 | 0.009 | 0.026 |
| WY | None | 0.006 | 0.018 |
| | $ES_{ng}$: | **1.024** | **3.073** |

# Appendix E - State-by-State Emission Savings Methodology and Results

By accounting for the energy savings for electricity and natural gas separately, the GHG emission reduction was able to be calculated more accurately. For electricity, eGRID provides emission factors for all GHGs by state making the calculation very simple. For natural gas, the equation is the same except a base emissions factor of 0.0053208 MTCO2e/therm was used since the factor does not vary based on plant type and location as with electricity. The equations used to calculate state-by-state emissions are shown below.

$$\boldsymbol{EM_{yy-e} = \left[\sum ES_{yy-zz-e} * CF_e * EF_{yy-e}\right](CR)(EL)}$$

**Equation 9: State Electricity Emissions Savings (MTCO2e)**

where,

$EM_{yy-e}$= Emission Savings for electricity in MTCO2e for yy state

$ES_{yy-zz-e}$= Energy Savings for electricity in BTU for a zz prototype building in yy state

$CF_e$ = Conversion Factor from BTU to kWH, 0.00029 is used

$EF_{yy-e}$ = Annual non-baseload Emissions Factor from eGrid for yy state in MTCO2e/kWH

$CR$ = Compliance Rate, either 0.25 or 0.75

$EL$ = Energy Loss factor for non-compliant buildings, 0.85 is used

and,

$$\boldsymbol{EM_{yy-ng} = \left[\sum ES_{yy-zz-ng} * CF_{ng} * EF_{ng}\right](CR)(EL)}$$

**Equation 10: State Natural Gas Emissions Savings (MTCO2e)**

where,

$ES_{yy-ng}$= Energy Savings for natural gas in BTU for yy state

$ES_{yy-zz-ng}$= Energy Savings for natural gas in BTU in zz prototype building in yy state

$CF_{ng}$ = Conversion Factor from BTU to therm, 0.00001 is used

$EF_{ng}$ = Annual Emissions Factor from eGrid in MTCO2e/therm, 0.0053208 is used

$CR$ = Compliance Rate, either 0.25 or 0.75

$EL$ = Energy Loss factor for non-compliant buildings, 0.85 is used

After the savings for each state is found, the savings for the whole country is found according to the equations below.

$$\boldsymbol{EM_e = \left[\sum EM_{yy-e}\right]}$$

**Equation 11: National Electricity Emissions Savings (MTCO2e)**

where,

$EM_e$= Electricity Emission Savings in MTCO2e for the country

$EM_{yy-e}$= Emission Savings for electricity in MTCO2e for yy state

and,

$$\boldsymbol{EM_{ng} = \left[\sum EM_{yy-ng}\right]}$$

**Equation 12: National Natural Gas Emissions Savings (MTCO2e)**

where,

$EM_{ng}$= Natural Gas Emission Savings in MTCO2e for the country

$EM_{yy-ng}$= Energy Savings for natural gas in MTCO2e for yy state

The state-by-state results for these calculations are shown in Table E.1 and Table E.2.

**Table E.1: State-by-State Annual Emission Savings for Electricity**

| Electricity | | | |
|---|---|---|---|
| State Abbreviation | Current Code Adopted | $EM_{yy-e}$ (MMTC02e) | |
| | | Low Case | High Case |
| AK | None | 0.00 | 0.01 |
| AL | 90.1-2007 | 0.05 | 0.14 |
| AR | 90.1-2007 | 0.02 | 0.06 |
| AZ | None | 0.08 | 0.23 |
| CA | 90.1-2010 | 0.00 | 0.00 |
| CO | None | 0.07 | 0.21 |

| | | | |
|---|---|---|---|
| CT | 90.1-2007 | 0.02 | 0.05 |
| DC | 90.1-2010 | 0.00 | 0.01 |
| DE | 90.1-2010 | 0.00 | 0.01 |
| FL | 90.1-2010 | 0.09 | 0.26 |
| GA | 90.1-2007 | 0.10 | 0.31 |
| HI | 90.1-2007 | 0.01 | 0.03 |
| IA | 90.1-2010 | 0.01 | 0.03 |
| ID | 90.1-2010 | 0.00 | 0.01 |
| IL | 90.1-2010 | 0.04 | 0.12 |
| IN | 90.1-2007 | 0.09 | 0.26 |
| KS | None | 0.04 | 0.11 |
| KY | 90.1-2010 | 0.01 | 0.04 |
| LA | 90.1-2007 | 0.03 | 0.09 |
| MA | 90.1-2010 | 0.01 | 0.03 |
| MD | 90.1-2013 | 0.00 | 0.00 |
| ME | None | 0.00 | 0.01 |
| MI | 90.1-2007 | 0.06 | 0.19 |
| MN | 90.1-2010 | 0.01 | 0.04 |
| MO | None | 0.07 | 0.21 |
| MS | 90.1-2010 | 0.01 | 0.02 |
| MT | 90.1-2010 | 0.00 | 0.01 |
| NC | 90.1-2007 | 0.10 | 0.30 |
| ND | None | 0.01 | 0.03 |
| NE | 90.1-2007 | 0.03 | 0.08 |
| NH | 90.1-2007 | 0.01 | 0.02 |
| NJ | 90.1-2007 | 0.04 | 0.12 |
| NM | 90.1-2007 | 0.01 | 0.04 |
| NV | 90.1-2010 | 0.01 | 0.04 |
| NY | 90.1-2010 | 0.02 | 0.07 |
| OH | 90.1-2007 | 0.12 | 0.35 |
| OK | None | 0.03 | 0.10 |
| OR | 90.1-2010 | 0.01 | 0.02 |
| PA | 90.1-2007 | 0.08 | 0.24 |
| RI | 90.1-2010 | 0.00 | 0.00 |
| SC | 90.1-2007 | 0.06 | 0.17 |
| SD | None | 0.01 | 0.03 |
| TN | None | 0.09 | 0.27 |
| TX | 90.1-2007 | 0.22 | 0.65 |
| UT | 90.1-2010 | 0.01 | 0.02 |
| VA | 90.1-2010 | 0.02 | 0.06 |
| VT | 90.1-2013 | 0.00 | 0.00 |

| | | | |
|---|---|---|---|
| WA | 90.1-2010 | 0.01 | 0.04 |
| WI | 90.1-2007 | 0.05 | 0.14 |
| WV | 90.1-2007 | 0.01 | 0.04 |
| WY | None | 0.01 | 0.02 |
| | $\boldsymbol{EM_e}$: | **1.77** | **5.31** |

**Table E.2: State-by-State Annual Emission Savings for Natural Gas**

| Natural Gas | | | |
|---|---|---|---|
| State Abbreviation | Current Code Adopted | $EM_{yy-ng}$ (MMTC02e) | |
| | | Low Case | High Case |
| AK | None | 0.001 | 0.002 |
| AL | 90.1-2007 | 0.001 | 0.003 |
| AR | 90.1-2007 | 0.001 | 0.002 |
| AZ | None | 0.001 | 0.004 |
| CA | 90.1-2010 | 0.000 | 0.000 |
| CO | None | 0.003 | 0.010 |
| CT | 90.1-2007 | 0.001 | 0.004 |
| DC | 90.1-2010 | 0.000 | 0.000 |
| DE | 90.1-2010 | 0.000 | 0.000 |
| FL | 90.1-2010 | 0.000 | 0.001 |
| GA | 90.1-2007 | 0.002 | 0.006 |
| HI | 90.1-2007 | 0.000 | 0.000 |
| IA | 90.1-2010 | 0.000 | 0.000 |
| ID | 90.1-2010 | 0.000 | 0.000 |
| IL | 90.1-2010 | 0.001 | 0.002 |
| IN | 90.1-2007 | 0.003 | 0.009 |
| KS | None | 0.001 | 0.004 |
| KY | 90.1-2010 | 0.000 | 0.000 |
| LA | 90.1-2007 | 0.001 | 0.002 |
| MA | 90.1-2010 | 0.000 | 0.001 |
| MD | 90.1-2013 | 0.000 | 0.000 |
| ME | None | 0.001 | 0.003 |
| MI | 90.1-2007 | 0.003 | 0.010 |
| MN | 90.1-2010 | 0.000 | 0.001 |
| MO | None | 0.003 | 0.008 |
| MS | 90.1-2010 | 0.000 | 0.000 |
| MT | 90.1-2010 | 0.000 | 0.000 |
| NC | 90.1-2007 | 0.002 | 0.007 |

| | | | |
|---|---|---|---|
| ND | None | 0.001 | 0.002 |
| NE | 90.1-2007 | 0.001 | 0.003 |
| NH | 90.1-2007 | 0.001 | 0.002 |
| NJ | 90.1-2007 | 0.002 | 0.007 |
| NM | 90.1-2007 | 0.000 | 0.001 |
| NV | 90.1-2010 | 0.001 | 0.002 |
| NY | 90.1-2010 | 0.001 | 0.002 |
| OH | 90.1-2007 | 0.004 | 0.013 |
| OK | None | 0.001 | 0.003 |
| OR | 90.1-2010 | 0.000 | 0.000 |
| PA | 90.1-2007 | 0.004 | 0.012 |
| RI | 90.1-2010 | 0.000 | 0.000 |
| SC | 90.1-2007 | 0.001 | 0.003 |
| SD | None | 0.001 | 0.002 |
| TN | None | 0.003 | 0.009 |
| TX | 90.1-2007 | 0.003 | 0.009 |
| UT | 90.1-2010 | 0.000 | 0.000 |
| VA | 90.1-2010 | 0.000 | 0.001 |
| VT | 90.1-2013 | 0.000 | 0.000 |
| WA | 90.1-2010 | 0.000 | 0.001 |
| WI | 90.1-2007 | 0.003 | 0.009 |
| WV | 90.1-2007 | 0.000 | 0.001 |
| WY | None | 0.000 | 0.001 |
| | $\boldsymbol{EM_{ng}}$: | **0.054** | **0.163** |

# Appendix F - State-by-State Cost Savings Methodology and Results

Annual energy cost savings were able to be calculated by taking the electricity and natural gas savings determined previously and multiplying those by utility sale costs by state according to the equations below.

$$\boldsymbol{AEC_{yy-e}} = \left[\sum \boldsymbol{ES_{yy-zz-e}} * \boldsymbol{CF_e} * \boldsymbol{ASF_{yy-e}}\right](\boldsymbol{CR})(\boldsymbol{EL})$$

**Equation 13: Annual State Electricity Energy Cost Savings (dollars)**

where,

$AEC_{yy-e}$= Annual Energy Cost Savings for electricity in dollars for yy state

$ES_{yy-zz-e}$= Energy Savings for electricity in BTU for a zz prototype building in yy state

$CF_e$ = Conversion Factor from BTU to kWH, 0.00029 is used

$ASF_{yy-e}$ = Annual Sales Factor in yy state from EIA in \$/kWH

$CR$ = Compliance Rate, either 0.25 or 0.75

$EL$ = Energy Loss factor for non-compliant buildings, 0.85 is used

and,

$$\boldsymbol{AEC_{yy-ng}} = \left[\sum \boldsymbol{ES_{yy-zz-ng}} * \boldsymbol{CF_{ng}} * \boldsymbol{ASF_{yy-ng}}\right](\boldsymbol{CR})(\boldsymbol{EL})$$

**Equation 14: Annual State Natural Gas Energy Cost Savings (dollars)**

where,

$AEC_{yy-ng}$= Annual Energy Cost Savings for natural in dollars for yy state

$ES_{yy-zz-ng}$= Energy Savings for natural gas in BTU in zz prototype building in yy state

$CF_{ng}$ = Conversion Factor from BTU to therm, 0.00001 is used

$ASF_{yy-ng}$ = Annual Sales Factor in yy state from EIA in \$/therm

$CR$ = Compliance Rate, either 0.25 or 0.75

$EL$ = Energy Loss factor for non-compliant buildings, 0.85 is used

After the savings for each state is found, the savings for the whole country is found according to the equations below.

$$AEC_e = \left[\sum AEC_{yy-e}\right]$$

**Equation 15: Annual National Electricity Energy Cost Savings (dollars)**

where,

$AEC_e$= Annual Energy Cost Savings for electricity in dollars for the country

$AEC_{yy-e}$= Annual Energy Cost Savings for electricity in dollars for yy state

and,

$$AEC_{ng} = \left[\sum AEC_{yy-ng}\right]$$

**Equation 16: Annual National Natural Gas Energy Cost Savings (dollars)**

where,

$AEC_{ng}$= Annual Energy Cost Savings for natural gas in dollars for the country

$AEC_{yy-ng}$= Annual Energy Cost Savings for natural in dollars for yy state

The state-by-state results for these calculations are shown in Table F.1 and Table F.2.

**Table F.1: State-by-State Annual Energy Cost Savings for Electricity**

| Electricity | | | |
|---|---|---|---|
| State Abbreviation | Current Code Adopted | $AEC_{yy-e}$ (Million $) | |
| | | Low Case | High Case |
| AK | None | 1.41 | 4.22 |
| AL | 90.1-2007 | 7.17 | 21.50 |
| AR | 90.1-2007 | 3.00 | 8.99 |
| AZ | None | 13.66 | 40.99 |
| CA | 90.1-2010 | 0.36 | 1.08 |
| CO | None | 8.68 | 26.03 |
| CT | 90.1-2007 | 5.38 | 16.14 |
| DC | 90.1-2010 | 0.47 | 1.40 |
| DE | 90.1-2010 | 0.28 | 0.84 |
| FL | 90.1-2010 | 14.32 | 42.95 |
| GA | 90.1-2007 | 12.50 | 37.49 |
| HI | 90.1-2007 | 3.41 | 10.23 |
| IA | 90.1-2010 | 0.81 | 2.43 |
| ID | 90.1-2010 | 0.52 | 1.55 |

| | | | |
|---|---|---|---|
| IL | 90.1-2010 | 3.72 | 11.17 |
| IN | 90.1-2007 | 8.64 | 25.93 |
| KS | None | 3.68 | 11.04 |
| KY | 90.1-2010 | 1.27 | 3.81 |
| LA | 90.1-2007 | 4.51 | 13.52 |
| MA | 90.1-2010 | 2.77 | 8.30 |
| MD | 90.1-2013 | 0.00 | 0.00 |
| ME | None | 1.80 | 5.41 |
| MI | 90.1-2007 | 7.62 | 22.86 |
| MN | 90.1-2010 | 1.32 | 3.97 |
| MO | None | 5.65 | 16.94 |
| MS | 90.1-2010 | 0.99 | 2.98 |
| MT | 90.1-2010 | 0.20 | 0.60 |
| NC | 90.1-2007 | 10.33 | 31.00 |
| ND | None | 0.62 | 1.85 |
| NE | 90.1-2007 | 2.01 | 6.02 |
| NH | 90.1-2007 | 2.24 | 6.73 |
| NJ | 90.1-2007 | 9.33 | 27.98 |
| NM | 90.1-2007 | 2.16 | 6.49 |
| NV | 90.1-2010 | 2.30 | 6.89 |
| NY | 90.1-2010 | 5.95 | 17.84 |
| OH | 90.1-2007 | 13.06 | 39.18 |
| OK | None | 3.93 | 11.79 |
| OR | 90.1-2010 | 1.03 | 3.08 |
| PA | 90.1-2007 | 10.71 | 32.13 |
| RI | 90.1-2010 | 0.46 | 1.38 |
| SC | 90.1-2007 | 7.49 | 22.47 |
| SD | None | 0.77 | 2.30 |
| TN | None | 9.66 | 28.97 |
| TX | 90.1-2007 | 32.22 | 96.65 |
| UT | 90.1-2010 | 1.04 | 3.13 |
| VA | 90.1-2010 | 2.36 | 7.07 |
| VT | 90.1-2013 | 0.00 | 0.00 |
| WA | 90.1-2010 | 1.85 | 5.55 |
| WI | 90.1-2007 | 6.04 | 18.12 |
| WV | 90.1-2007 | 1.23 | 3.68 |
| WY | None | 0.56 | 1.68 |
| **Total:** | $AEC_e$: | **241.45** | **724.36** |

**Table F.2: State-by-State Annual Energy Cost Savings for Natural Gas**

| Natural Gas | | | |
|---|---|---|---|
| State Abbreviation | Current Code Adopted | $AEC_{yy-ng}$ (Million $) | |
| | | Low Case | High Case |
| AK | None | 0.103 | 0.309 |
| AL | 90.1-2007 | 0.195 | 0.584 |
| AR | 90.1-2007 | 0.084 | 0.251 |
| AZ | None | 0.218 | 0.653 |
| CA | 90.1-2010 | 0.018 | 0.054 |
| CO | None | 0.444 | 1.331 |
| CT | 90.1-2007 | 0.219 | 0.657 |
| DC | 90.1-2010 | 0.003 | 0.009 |
| DE | 90.1-2010 | 0.004 | 0.012 |
| FL | 90.1-2010 | 0.082 | 0.245 |
| GA | 90.1-2007 | 0.331 | 0.994 |
| HI | 90.1-2007 | 0.029 | 0.088 |
| IA | 90.1-2010 | 0.021 | 0.062 |
| ID | 90.1-2010 | 0.014 | 0.043 |
| IL | 90.1-2010 | 0.107 | 0.322 |
| IN | 90.1-2007 | 0.414 | 1.243 |
| KS | None | 0.215 | 0.644 |
| KY | 90.1-2010 | 0.020 | 0.061 |
| LA | 90.1-2007 | 0.091 | 0.273 |
| MA | 90.1-2010 | 0.057 | 0.172 |
| MD | 90.1-2013 | 0.000 | 0.000 |
| ME | None | 0.204 | 0.613 |
| MI | 90.1-2007 | 0.476 | 1.427 |
| MN | 90.1-2010 | 0.059 | 0.178 |
| MO | None | 0.446 | 1.338 |
| MS | 90.1-2010 | 0.003 | 0.008 |
| MT | 90.1-2010 | 0.011 | 0.033 |
| NC | 90.1-2007 | 0.377 | 1.132 |
| ND | None | 0.062 | 0.187 |
| NE | 90.1-2007 | 0.108 | 0.323 |
| NH | 90.1-2007 | 0.144 | 0.431 |
| NJ | 90.1-2007 | 0.426 | 1.279 |
| NM | 90.1-2007 | 0.027 | 0.082 |
| NV | 90.1-2010 | 0.086 | 0.257 |
| NY | 90.1-2010 | 0.110 | 0.331 |
| OH | 90.1-2007 | 0.506 | 1.519 |

| | | | |
|---|---|---|---|
| OK | None | 0.142 | 0.427 |
| OR | 90.1-2010 | 0.015 | 0.044 |
| PA | 90.1-2007 | 0.767 | 2.301 |
| RI | 90.1-2010 | 0.008 | 0.023 |
| SC | 90.1-2007 | 0.150 | 0.451 |
| SD | None | 0.060 | 0.181 |
| TN | None | 0.473 | 1.418 |
| TX | 90.1-2007 | 0.416 | 1.247 |
| UT | 90.1-2010 | 0.018 | 0.055 |
| VA | 90.1-2010 | 0.037 | 0.112 |
| VT | 90.1-2013 | 0.000 | 0.000 |
| WA | 90.1-2010 | 0.037 | 0.110 |
| WI | 90.1-2007 | 0.381 | 1.143 |
| WV | 90.1-2007 | 0.073 | 0.218 |
| WY | None | 0.039 | 0.117 |
| | $AEC_{ng}$: | **8.331** | **24.992** |

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Citation: CAIT Climate Data Explorer. 2015. Washington, DC: World Resources Institute. Available online at: http://cait.wri.org

Best,
Johannes

**Johannes Friedrich**
*Associate*
**World Resources Institute**

AP Alexander Pint
To: JFriedrich@wri.org;
Reply all
Fri 10/2/2015 2:25 PM

Sent Items

Dear Mr. Friedrich,

I am a graduate student at Kansas State University studying Architectural Engineering. In preparing my final Masters Report titled "Building Energy Codes and their Impact on Greenhouse Gas Emissions in the U.S." I would like to use a graphic found from your blog post "The History of Carbon Dioxide Emissions" depicting the top ten greenhouse gas emitters from 2011. The bar graph is both highly relevant to my topic and integral to the support of my paper.

May I please have permission to use this graphic? It will be appropriately cited and credited to you and your blog post.

Please contact me if you have any questions regarding my use of these graphics or anything else.

Thanks for your help,

Alex Pint
Architectural Engineering
Kansas State University
913.991.8217 | apint@ksu.edu

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KW Katie Weeks <katie.weeks@imt.org>

To: Alexander Pint;

Fri 10/2/2015 3:17 PM

Hi Alex,

Yes, no problem.

Katie

Katie Weeks, LEED Green Associate
Director of Communications
Institute for Market Transformation
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(202) 525-2883 x306 (direct) | (347) 524-0458 (mobile)
katie.weeks@imt.org | www.imt.org | @IMT_speaks

*Please pass it on: IMT is hiring*

---

AP Alexander Pint

Reply all

To: katie.weeks@imt.org;

Fri 10/2/2015 3:11 PM

Sent Items

Dear Ms. Weeks,

I am a graduate student at Kansas State University studying Architectural Engineering. In preparing my final Masters Report titled "Building Energy Codes and their Impact on Greenhouse Gas Emissions in the U.S.", I would like to use a graphic found from a report published by the IMT titled "Analysis of Job Creation and Energy Cost Savings from Building Energy Rating and Disclosure Policy." This report was retrieved from http://www.imt.org/uploads/resources/files/Analysis_Job_Creation.pdf

The graphic I would like to use shows the employment benefits from capital upgrades (located on pg. 15 of the report). This graphic is both highly relevant to my topic and integral to the support of my paper.

May I please have permission to use this graphic? It will be appropriately cited and credited to IMT and the report.

Please contact me if you have any questions regarding my use of this graphic or anything else.

Thanks for your help,

Alex Pint
Architectural Engineering
Kansas State University
913.991.8217 | apint@ksu.edu

## Permission 3: PNNL

HR Hart, Reid <reid.hart@pnnl.gov>
To: Alexander Pint;
Fri 10/2/2015 4:00 PM

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AP Alexander Pint
To: Reid.Hart@pnnl.gov <reid.hart@pnnl.gov>;
Reply all
Fri 10/2/2015 3:38 PM

Sent Items

Dear Mr. Hart,

I am a graduate student at Kansas State University studying Architectural Engineering. In preparing my final Masters Report titled "Building Energy Codes and their Impact on Greenhouse Gas Emissions in the U.S.", I would like to use graphics found from a report you and collaborators published titled "National Cost-effectiveness of ANSI/ASHRAE/IES Standard 90.1-2013".

The graphics I would like to use summarize the life cycle cost net savings, the simple payback, and the scalar ratio for ASHRAE 90.1-2013. These graphics are both highly relevant to my topic and integral to the support of my paper.

May I please have permission to use these graphics? It will be appropriately cited and credited to you, your collaborators and the report.

Please contact me if you have any questions regarding my use of these graphics or anything else.

Thanks for your help,

Alex Pint
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To: Alexander Pint;

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AP Alexander Pint
To: permissions@ashrae.org;

Sun 10/4/2015 3:13 PM

Hello,

I am a graduate student at Kansas State University studying Architectural Engineering. In preparing my final Masters Report titled "Building Energy Codes and their Impact on Greenhouse Gas Emissions in the U.S.", I would like to use Table B-1 found from ASHRAE 90.1-2010.

The table I would like to use shows a list of states and counties classified by climate zone. This table is both highly relevant to my topic and integral to the support of my paper.

May I please have permission to use this graphic? It will be appropriately cited and credited to ASHRAE and the code.

Please contact me if you have any questions regarding my use of this graphic or anything else.

Thanks for your help,

Alex Pint
Architectural Engineering
Kansas State University
913.991.8217 | apint@ksu.edu

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| **Publication:** | Environmental Science & Technology |
| **Publisher:** | American Chemical Society |
| **Date:** | Dec 1, 2014 |

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| **Publication:** | Environmental Science & Technology |
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# Permission 10: Ecometrica

## Use of Graphic from "Greenhouse Gases... What Do all These Terms Mean?"

HK Heather Kirby <heather.kirby@ecometrica.com>
To: Alexander Pint;

Hi Alexander,

I have also spoken with our Head of Marketing on your behalf and he is happy for you to use the graphic as you have outlined in your request.

Good luck with your report.

All the best,

Heather


**Heather Kirby** | Office Manager

ecometrica

London | Boston | Edinburgh | Montreal

**Main: +44 (0)131 662 4342** **Email: heather.kirby@ecometrica.com**

Mob: +44 (0)777 222 1096 Web: www.ecometrica.com

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AP Alexander Pint
To: info@ecometrica.com;

Reply all
Tue 10/13/2015 3:08 PM

Sent Items

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Hello,

I am a graduate student at Kansas State University studying Architectural Engineering. In preparing my final Masters Report titled "Building Energy Codes and their Impact on Greenhouse Gas Emissions in the U.S.", I would like to use a graphic found from an article published by Ecometrica titled "Greenhouse Gases, CO2, CO2e, and Carbon: What Do All These Terms Mean?". This report was retrieved from http://ecometrica.com/assets/GHGs-CO2-CO2e-and-Carbon-What-Do-These-Mean-v2.1.pdf

The graphic I would like to use shows different greenhouse gases along with their respective global warming potentials. This graphic is both highly relevant to my topic and integral to the support of my paper.

May I please have permission to use this graphic? It will be appropriately cited and credited to Ecometrica and the report.

Please contact me if you have any questions regarding my use of this graphic or anything else.

Thanks for your help,


Alex Pint
Architectural Engineering
Kansas State University
913.991.8217 | apint@ksu.edu

# Permission 11: ACEEE

Use of Graphics from "2014 International Energy Efficiency Scorecard"

ES Eric Schwass <ESchwass@aceee.org>
To: Alexander Pint;
Tue 10/13/2015 3:46 PM

Hello Mr. Pint,

You have permission to use the graphic as described in your email. Good luck on your paper!

Eric Schwass
American Council for an Energy-Efficient Economy
529 14th Street NW, Suite 600
Washington, DC 20045
202.507.4017
http://aceee.org

**From:** aceeeinfo
**Date:** Tuesday, October 13, 2015 at 4:41 PM
**To:** Eric
**Subject:** FW: Use of Graphics from "2014 International Energy Efficiency Scorecard"

AP Alexander Pint
To: aceeeinfo@aceee.org;
Reply all
Mon 10/12/2015 2:09 PM

Sent Items

Hello,

I am a graduate student at Kansas State University studying Architectural Engineering. In preparing my final Masters Report titled "Building Energy Codes and their Impact on Greenhouse Gas Emissions in the U.S.", I would like to use a graphic found from a report published by ACEEE titled "2014 International Energy Efficiency Scorecard" This report was retrieved from http://aceee.org/research-report/e1402

The graphic I would like to use shows the score and rank of the countries in scorecard. This graphic is both highly relevant to my topic and integral to the support of my paper.

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Thanks for your help,

Alex Pint
Architectural Engineering
Kansas State University
913.991.8217 | apint@ksu.edu

# Permission 12: JCIBE

Use of Graphics from Multiple Reports from the Institute for Building Efficiency

Jennifer Layke <JLayke@wri.org>
To: Alexander Pint; Cc: Kari Pfisterer <kari.b.pfisterer@jci.com>;

Reply all

Thu 11/5/2015 10:45 AM

Inbox

Action Items

Hello Alex, and thank you for reaching out. We are delighted to grant you permission to use and reference the material you mention from our Institute for Building Efficiency research, with attribution.

We would also welcome the chance to learn from your research and analysis. Please send a copy of your MS report if it will be made publicly available.

I have cc'd Johnson Controls as well in this email, for their records.

With my best regards,
Jennifer

Alexander Pint
To: jlayke@wri.org <JLayke@wri.org>;

Wed 11/4/2015 4:38 PM

Hello Ms. Layke,

I am a graduate student at Kansas State University studying Architectural Engineering. In preparing my final MS Report titled "Building Energy Codes and their Impact on Greenhouse Gas Emissions in the U.S.", I would like to use graphics found from reports that the Institute for Building Efficiency coordinated titled "2013 Energy Efficiency Indicator Survey" and "Achieving Scale with Energy Efficiency ". I understand that the new partnership between WRI and JCI means that the Institute for Building Efficiency website is no longer being updated. If you do not have authorization to grant me permission to use these graphics, I would appreciate any help you could provide by referring me to the correct person to contact.

The graphics I would like to use show various survey results: one from global executives on methods to improve energy efficiency economics and one about financial barriers to energy efficiency. The former is on p. 14 of the "2013 Energy Efficiency Indicator Survey" and the latter is on p. 4 of "Achieving Scale with Energy Efficiency". These graphics are both highly relevant to my topic and integral to the support of my paper.

May I please have permission to use these graphics? It will be appropriately cited and credited to the Institute for Building Efficiency and both reports.

Please contact me if you have any questions regarding my use of these graphics or anything else.

Thanks for your help,

Alex Pint
Architectural Engineering
Kansas State University
913.991.8217 | apint@ksu.edu