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

Building Energy Codes Program: National Benefits Assessment, 1992–2040

OV Livingston
DB Elliott
PC Cole
R Bartlett

March 2014

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

Commercial and residential buildings account for approximately 41% of all energy consumption and 72% of electricity usage in the United States. Building energy codes and standards set minimum requirements for energy-efficient design and construction for new and renovated buildings, assuring reductions in energy use and greenhouse gas emissions over the life of buildings. The U.S. Department of Energy (DOE), through the Building Energy Codes Program (BECP or the Program), supports the improvement of energy efficiency in buildings. The BECP was founded 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. Since its inception 20 years ago, BECP has become the central information resource on national energy codes and standards.

The BECP consists of an integrated portfolio of activities to increase energy efficiency in buildings. As part of its code development activities, DOE participates in the development of model energy codes and standards maintained by the International Code Council (ICC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). To help states adopt and implement progressive energy codes, DOE provides: 1) technical assistance to state and local governments to help facilitate the adoption process and 2) an array of resources to building industry stakeholders and enforcement officials to improve code compliance, including compliance software tools, training materials, and technical support.

BECP periodically assesses the impacts of its activities by estimating historical and projected energy savings, consumer savings, and avoided emissions. The Pacific Northwest National Laboratory (PNNL) conducted the codes benefits assessment in support of the BECP. Underlying the assessment is a series of calculations that estimate and compare energy savings under two scenarios: "with BECP" and "without BECP." The analysis covers the years 1992−2040 and includes comparing the nominal energy savings (assuming 100 percent adoption and compliance) attributable to different code versions, determining the applicable floor space (both residential and commercial) subject to the code, and estimating the final energy savings by adjusting nominal energy savings for the applicable floor space according to the estimated actual adoption and compliance levels. The resulting estimates of energy consumption for each scenario are compared, and the difference equals the impact of BECP activities.

The results of the Program impacts are presented in terms of energy savings, consumer cost savings, and avoided emissions. Energy savings include site, primary (source) and full-fuel-cycle (FCC) savings. Table ES.1 summarizes BECP historical and projected energy savings and net present value of consumer benefits (energy cost savings). Figure ES.1 shows the annual FFC energy savings from BECP activities from 1992−2040. A summary of emissions savings is presented in Table ES.2.

Since the inception of the Program 20 years ago, cumulative FFC energy savings from 1992− 2012 are estimated to be approximately 4.2 quads and cost savings to consumers have been more than $44 billion. These savings have resulted primarily from the Program's activities which upgrade the model energy codes, accelerate their adoption by states and localities, and improve code compliance by means of various software tools and other types of training and technical support. The federal budgetary cost of the Program over this same period (1992−2012) was estimated to be around $110 million, resulting in a ratio of more than $400 in cost savings for each DOE program dollar spent.

The estimated cumulative benefits from the Program through 2040 are also significant. The cumulative energy savings attributed to the Program total nearly 46 quads of FFC energy in 2040, or 44 quads of primary energy, equivalent to almost an entire year's worth of primary energy consumption from the U.S. residential and commercial sectors at current consumption rates. The Program is estimated to save consumers up to $230 billion on their utility bills by 2040. Annual carbon savings reach 36 million tons at the end of 2012, and the cumulative savings by 2040 are estimated at 3,478 million tons.

Table ES.1. Summary of Energy and Cost Savings from BECP Energy Code Activities

	Site Energy Savings,(a) quads	**Primary Energy Savings,(b) quads**	**FFC Energy Savings,(c) quads**	**Energy Cost Savings NPV, billion 2012$**
Historical				
Annual in 2012	0.2	0.48	0.5	5.0
Cumulative 1992−2012	2.0	4.0	4.2	44.6
Projected, 2013−2040 Construction				
Annual in 2040	1.2	2.2	2.3	5.2
Cumulative 2013−2040	22.0	40.1	41.6	185.7
BECP Total				
Annual in 2040	1.2	2.2	2.3	5.2
Cumulative 1992−2040	24.0	44.1	45.7	230.3

(a) Site energy savings represent direct energy savings to the consumer. Site energy savings multiplied by the energy price represent energy cost savings to the consumer.

(b) Following the analysis methodology used by DOE's Appliance and Equipment Standards Program, site energy savings were first converted to the source energy terms, which includes energy used in generation, transmission, and distribution (primary energy).

(c) Energy used further "upstream" in the mining, processing, and transportation of fuels cycle was calculated using the NIA PLUS model and added to the primary energy savings to yield full-fuel-cycle (FFC) energy savings

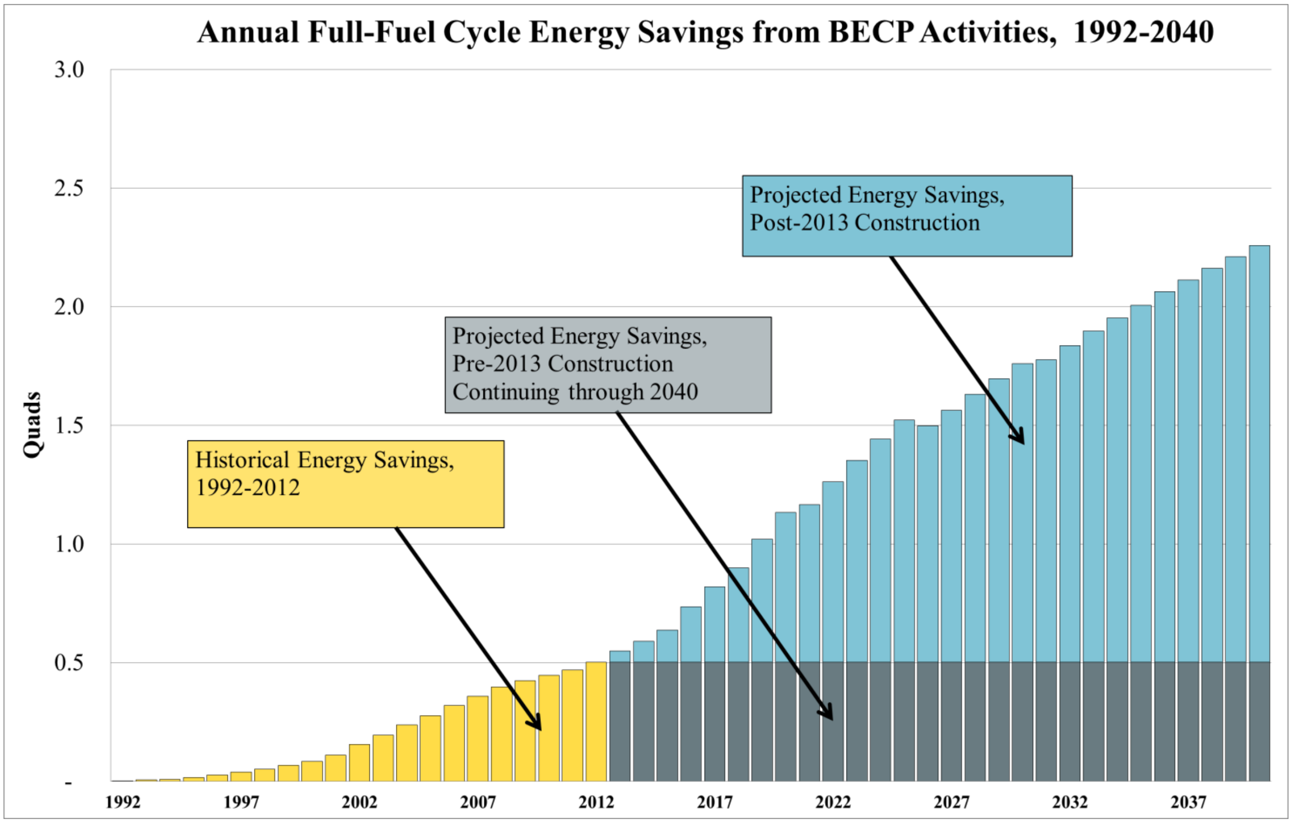

Figure ES.1. Annual Full-Fuel-Cycle Energy Savings from BECP Activities, 1992–2040

Table ES.2. Summary of Historical and Projected Emissions Savings

	CO_2 (mmt)	**NO_x (kt)**	**Mercury (ton)**	**N_2O (kt)**	**N_2O (mmt CO_2eq)**	**CH_4 (kt)**	**CH_4 (mmt CO_2eq)**	**SO_2 (kt)**
Historical								
Annual in 2012	36	80	0.1	0.4	0.1	159	4	46
Cumulative 1992–2012	300	664	0.6	3.3	1.0	1,347	34	386
Projected, 2013–2040 Construction								
Annual in 2040	185	194	0.4	1.8	0.5	796	20	116
Cumulative 2013–2040	3,178	3,855	6.9	32.1	9.6	14,095	352	3,489
BECP Total								
Annual in 2040	185	194	0.4	1.8	0.5	796	20	116
Cumulative 1992–2040	3,478	4,519	7.6	35.4	10.5	15,441	386	3,875

BECP's cumulative FFC savings of emissions of the greenhouse gases of carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) in CO_2-equivalents in Table ES.2 are almost3.9 billion metric tons. That is equivalent to three-quarters of all energy-related emissions of the United States in 2012. These benefits do not count the reduction of other energy-related air pollutants shown in Table ES.2, or billions of dollars in saved future investment in facilities to supply the natural gas, electricity, and fuel oil to the residential and commercial sectors that would no longer be required.

This analysis also estimated the potential energy savings for 2013–2040 for residential and commercial code activities under ideal adoption and compliance conditions. The estimate represents the energy, cost, and emissions that could be saved on new post-2013 construction, as well as existing stock, with immediate code adoption and 100% compliance. Full cumulative site energy savings potential for 2013–2040 equals 42.6 quads, with residential and commercial energy code activities contributing approximately 50% each. Primary energy savings potential is 77 quads, which translates to FFC energy savings of nearly 80 quads. Cumulative energy cost savings potential equals approximately $330 billion (2012$). Annual CO_2 savings potential reaches 461 million metric tons at the end of 2040, and the cumulative potential carbon savings by 2040 are estimated at over 6.2 billion metric tons of CO_2. For more details of the energy savings potential, as well as potential cost and emissions reductions, refer to Appendix A.

Acronyms and Abbreviations

AEO	Annual Energy Outlook
ARRA	American Recovery and Reinvestment Act
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BECP	Building Energy Codes Program
CBECS	Commercial Buildings Energy Consumption Survey
CH_4	methane
CO_2	carbon dioxide
CO_2eq	carbon dioxide equivalent
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EUI	energy use intensity
FFC	full-fuel-cycle
Hg	mercury
hh	household
HVAC	heating, ventilating, and air conditioning
ICC	International Code Council
IECC	International Energy Conservation Code
GDP	gross domestic product
kt	kiloton
kWh	kilowatt-hours
MCEC	Model Code for Energy Conservation
MEC	Model Energy Code
MHC	McGraw-Hill Construction
Mt	metric ton
mmt	million metric tons
N_2O	nitrous oxide
NEMS	National Energy Modeling System
NO_x	nitrogen oxide
NPV	net present value
PNNL	Pacific Northwest National Laboratory
quads	quadrillion British thermal units
RECS	Residential Energy Consumption Survey
TBtu	trillion British thermal units

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1.0 Introduction

Buildings account for approximately 41% of all energy consumption and 72% of electricity usage in the United States. Building energy codes and standards set minimum requirements for energy-efficient design and construction for new and renovated buildings, assuring reductions in energy use and greenhouse gas emissions over the life of buildings. The U.S. Department of Energy (DOE), through the Building Energy Codes Program (BECP or the Program), supports the improvement of energy efficiency in buildings. BECP was founded in 1992 in response to the Energy Policy Act of 1992 (EPAct 1992), which mandated that DOE participate in the model national codes development process and that DOE help states adopt and implement progressive energy codes. Since its inception 20 years ago, BECP has become the central information resource on national energy codes and standards.

The BECP consists of an integrated portfolio of activities to increase energy efficiency in buildings. As part of its code development activities, DOE participates in the development of model energy codes and standards maintained by the International Code Council (ICC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). To help states adopt and implement progressive energy codes, DOE provides: 1) technical assistance to state and local governments to help facilitate the adoption process and 2) an array of resources to building industry stakeholders and enforcement officials to improve code compliance, including compliance software tools, training materials, and technical support.

BECP periodically assesses the influence of its activities by estimating historical and projected energy savings, consumer savings, and avoided emissions. This technical report describes the impacts of BECP energy code activities on the nation as a whole, expressed in terms of estimated site, primary (source), and full-fuel-cycle (FFC) energy savings, consumer energy cost savings, and emissions reductions. The analysis period included estimation of the historical (1992–2012) and projected (2013–2040) benefits of these activities. The methodology and assumptions used in the impacts analysis are discussed in detail in this report.

Impacts of the BECP are estimated under two different scenarios: "with BECP" and "without BECP." The difference between these two scenarios, in terms of energy, cost, and emissions is a measure of the Program's impact:

- The first scenario, "with BECP," is based on BECP having supported the development of more efficient national energy codes, provided technical assistance and training to states and localities, and developed and supported energy code-related materials and software. All of these activities are deemed to have improved the energy efficiency impact of the code requirements, and to have increased adoption of and compliance with building energy codes beyond what would have been likely without the Program.
- The second, "without BECP," follows the same computational steps as the first scenario, but with an alternative set of assumptions to describe what would have happened if the BECP had not been in place (i.e., a counterfactual scenario). As a result of other (i.e., non-DOE) code organizations that support building energy codes and state- and regionally-funded activities to adopt and enforce the codes, energy savings would still have occurred without the BECP, but at a slower pace and with a lower compliance rate.

This report is organized into five sections. Section 2 explains the impact analysis methodology. Sections 3 and 4 include detailed discussion of the assumptions and estimation results for BECP commercial and residential energy code activities, respectively. Section 5 summarizes the national energy and emissions savings, and economic benefits. Section 6 provides a list of references, and Section 7 provides a bibliography. The Appendix contains an estimate of the energy savings potential for residential and commercial code activities assuming immediate adoption and full compliance.

2.0 Methodology

This section describes the methodology used by PNNL to assess the impact of BECP energy code activities. Underlying the analysis is a series of calculations that estimate and compare the energy savings under two adoption and compliance scenarios: "with BECP" and "without BECP."

The steps used to calculate the "with BECP" scenario are as follows:

1. Select base (or reference) year.
2. Compare the nominal energy savings.
3. Determine applicable floor space subject to the code.
4. Estimate the final energy savings by adjusting nominal energy savings for the applicable floor space according to the estimated actual adoption and compliance levels.

These calculations rely on historical data or retrospective estimates, as well as future projections of code efficiency, adoption, and compliance to derive the energy consumption with the Program activities taking place. In the absence of reliable data or established analysis to use as bases for this analysis, the impact estimates also rely on fundamental or enabling assumptions developed based on analyst or Program experience and judgment.

To identify how much of the savings are attributable to the BECP, a second (counterfactual) scenario was used to investigate the probable impact had the Program not been in place. This second scenario, "without BECP," follows the same computational steps outlined above, but uses an alternative set of assumptions to describe what might have occurred differently without the BECP. For this analysis, BECP programmatic impacts are primarily defined as a) improvement of code energy efficiency, b) acceleration of adoption and c) increase in compliance. The nominal energy savings for the applicable floor area are adjusted for "with BECP" and "without BECP" scenarios. They are further adjusted by a different set of adoption and compliance rates. Figure 2.1 shows a brief outline of the computational steps for both scenarios.

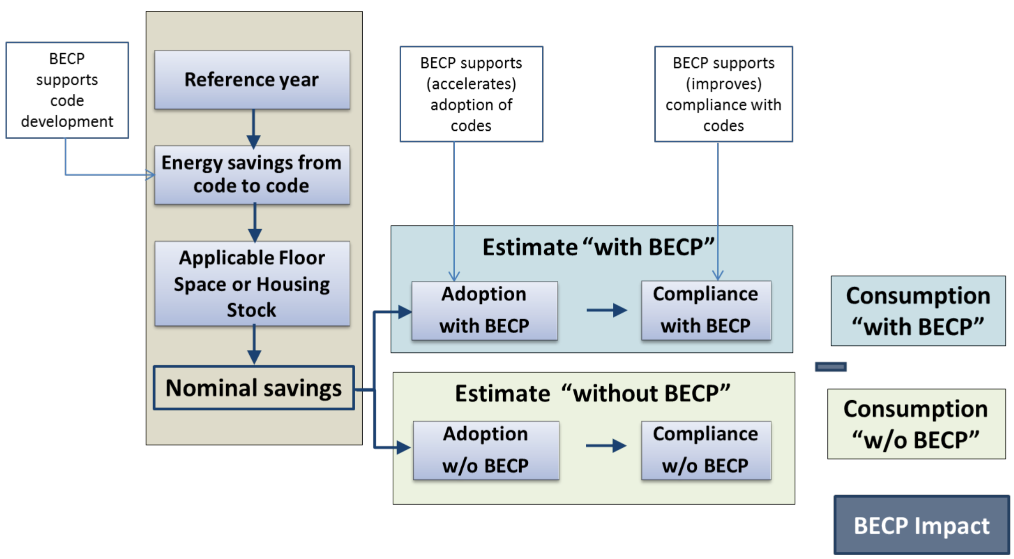

Figure 2.1. Analysis Methodology

The difference between estimates of energy consumption under the two scenarios determines the BECP programmatic impact (i.e., the portion of achieved energy savings that can be attributed to the BECP).

BECP selected 1992 as the base year for the impact analysis mainly because the Program was founded in 1992 in response to EPAct 1992. Other factors contributing to this decision include:

- The 1992 Model Energy Code (MEC) was mentioned in EPAct 1992, establishing it as a reasonable base year.
- Although many states had adopted ASHRAE Standard 90, the Model Code for Energy Conservation (MCEC 1977), or the MEC by the early 1980s, and a case can be made for using any one of these version years as the base year, lack of data on compliance with these codes and standards renders them infeasible as reference points.
- The use of 1992 as the reference year eliminates the need to consider an additional code level in the analysis of building practices less stringent than Standard 90A-1980. Additional code-level analysis would have added little to the accuracy of the estimates due to the aforementioned lack of data for that period.

Although using 1992 as the base year for the historical analysis might omit some of DOE's historical impact on building codes, it can be argued that most of DOE's influence on the technical requirements in these standards has occurred since 1992. DOE was not active in preparing and submitting proposed changes to the MEC during the 1980s. The majority of DOE's technically focused energy codes and standards activities in the 1980s targeted developing the technical foundation for ASHRAE Standard 90.1-1989 (ASHRAE 1990). This standard was much more rigorous than Standard 90A-1980 and thus had a greater impact on energy efficiency as states began to adopt Standard 90.1-1989 in the early 1990s.

For this analysis, estimated benefits were developed separately for commercial and residential energy codes. As such, estimates of code-to-code savings, applicable floor area, code adoption, and code compliance assumptions were developed separately as well. Section 3 contains detailed descriptions of the logic, assumptions, and estimation results for the commercial code activities, while Section 4 discusses similar points for the residential analysis.

3.0 Commercial Assumptions and Estimated Results

This section discusses how the energy savings attributable to different commercial energy code versions were compared, how the applicable commercial floor space subject to the code was determined, and what adoption and compliance assumptions were used in the analysis.

3.1 Commercial Energy Codes and Standards Performance (Code-to-Code Savings)

PNNL assessed relative energy use for commercial buildings designed to meet building design requirements found in the 2010, 2007, and 2004 versions of ASHRAE Standard 90.1. PNNL also evaluated the energy savings achieved by using Standard 90.1-2010 (ASHRAE 2010) over its predecessors, Standard 90.1-2007 (ASHRAE 2007), and Standard 90.1-2004 (ASHRAE 2004). The estimated values were also used to infer the savings from earlier versions of the code.

The evaluation was conducted using computer simulations of prototype buildings developed by PNNL to support the quantitative analysis of DOE's Determinations on ASHRAE Standard 90.1.[1] The annual energy use by fuel type and end use, extracted from the simulations, was converted to energy use intensity (EUI), expressed in energy use per square foot. Using construction weighting factors by building type and state, developed from 5 years of recent construction data, the energy use estimates were aggregated for each revision of Standard 90.1, both by building prototype and weighted across building type.

The analysis of relative energy use and energy savings for the 2004, 2007, and 2010 versions of Standard 90.1 was conducted using 16 commercial building prototypes based on published Commercial Prototype Building Models[2]. Every prototype building was simulated in each of the 15 U.S. climate zones used in the analyzed versions of Standard 90.1. For each climate zone, a most representative location and corresponding typical meteorological year weather file were identified, resulting in 720 climate/prototype combinations.[3]

The 2004, 2007, and 2010 versions of Standard 90.1 contain tables that specify efficiency requirements for heating, ventilating, and air conditioning (HVAC) and service water heating equipment. Most, but not all, of the equipment classes shown in the Standard 90.1 tables have minimum federal efficiency standards applied to them. Because mandated equipment efficiency is enforced as a manufacturing standard regardless of whether it is represented in Standard 90.1, the inclusion of the requirement in the ASHRAE standard has no separate energy impact. Therefore, it is necessary to exclude from the calculation the energy savings that would occur in new building construction due to these mandated equipment efficiency improvements. Excluding credit for this equipment in the quantitative analysis is consistent with the approach used in previous DOE Determinations. Therefore,

[1] For DOE's Determinations, go to http://www.energycodes.gov/regulations.
[2] The models are available at: http://www.energycodes.gov/development/commercial/90.1_models.
[3] For a more detailed discussion of the prototypes, technical assumptions, analyzed addenda, and aggregation weights, refer to the PNNL report, *Achieving 30% Goal: Energy and Cost Saving Analysis of ASHRAE/IES Standard 90.1-2010* (Thornton et al. 2011).

the code-to-code savings used in the BECP commercial benefits analysis explicitly exclude savings induced by the federal equipment efficiency standards.

The results of the Standards 90.1-2004 and 90.1-2007 analysis reported in the Standard 90.1-2007 Determination (Halverson et al. 2011a) are based on equipment efficiency requirements in Standard 90.1-2004. The results of the Standards 90.1-2007 and 90.1-2010 analysis reported in the Standard 90.1-2010 Determination (Halverson et al. 2011b) are based on equipment efficiency requirements in Standard 90.1-2007. Some of the equipment efficiency requirements are different between 90.1-2004 and 90.1-2007. To compare the saving impacts of the three standards (i.e., 90.1-2004, 2007, and 2010) and exclude those differences that are not direct results of the standard improvement, the energy saving results of Standard 90.1-2004 were not directly taken from the 90.1-2007 Determination report. The savings were calculated by subtracting the percentage differences between 90.1-2004 and 90.1-2007 reported in the 90.1-2007 Determination from results of 90.1-2007 reported in the 90.1-2010 Determination. The energy saving results of 90.1-2007 and 90.1-2010 from the 90.1-2010 Determination were used in this impact analysis without modification.

EUIs for each of the compared versions were analyzed by prototype and by climate location. For each prototype building, the energy consumption for each standard was modeled based on 15 representative climate locations, covering all ASHRAE climate zones. It was assumed that the energy consumption of a building at one of the climate locations could be represented by the same building at another location within the same ASHRAE climate zone, resulting in 111 representative locations. Simulated energy consumption across the 111 locations and the building types was normalized by the building floor area. Floor area assumptions for each of the prototypes used in the normalization are included in Table 3.1.

Table 3.1. Prototype Floor Area Assumptions

Building Type	Building Prototype	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 Healthcare	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	84,320

Resulting EUIs per square foot of floor area were weighted across building types and representative climate locations to obtain the aggregate EUIs by state.

To estimate the construction weights, the disaggregated construction volume data were acquired from the McGraw-Hill Construction (MHC) Project Starts Database. The MHC database obtained covers the time period 2003–2010, and depending upon the specific calculations, data from subsets of that time period were used. This MHC database was analyzed to develop detailed construction weights by climate zones, subzones, and states using the methodology outlined in Jarnagin and Bandyopadhyay (2010).

State-level aggregation produced estimates of the energy performance for the 2004, 2007, and 2010 versions of Standard 90.1 for two fuels (electricity and natural gas), and two groups of end uses (HVAC and Lighting/Other). The HVAC end use group includes heating, cooling, fan, pump, and heat rejection. Lighting/Other includes interior and exterior lighting, plug and process loads, service hot water, refrigeration, and generators. The estimates grouped by fuel type are presented in Table 3.2 and Table 3.3.

The impact analysis used state-level EUIs as a foundation for estimating the energy performance of the standards prior to Standard 90.1-2004 and following Standard 90.1-2010. For the versions predating 90.1-2004, the energy performance was estimated based on the commercial code improvement index developed by PNNL. The index is presented in Figure 3.1.

The retroactive code performance scalars for versions between Standard 90A-1980 and Standard 90.1-2001 were developed from this index using Standard 90.1-2004 as the base. For the versions prior to Standard 90.1-2004, BECP is not credited with the energy improvements related to code development. For Standards 90.1-2004, 2007, and 2010, BECP is credited with a third of the code-to-code energy efficiency improvement based on the professional judgment of the PNNL staff supporting code development. This means that if there were an 18.5% reduction in the EUI between Standards 90.1-2007 and 90.1-2010 in the "with BECP" scenario, we assumed that without DOE assistance in place, the code would have instead advanced by about 13%.

For future standard versions after Standard 90.1-2010, the energy use was calculated for two scenarios ("with BECP" and "without BECP") with Standard 90.1-2010 as the base. It was assumed that "with BECP" there would be a 7% improvement in the energy use, while a 6.3% improvement is expected without the DOE program in place, i.e., only 10% of the code-to-code energy efficiency improvement is attributed to BECP. This attribution structure is based on the professional judgment of the PNNL staff supporting code development and is consistent with BECP focusing on code development in the past and shifting more towards supporting improvement in code compliance in the future.

Nominal code-to-code savings were derived from the energy use estimates by comparing the code version that was adopted in the state to the previously active code version. Nominal energy savings were then adjusted by the compliance rates. Commercial adoption and compliance assumptions are described in Sections 3.3 and 3.4.

Table 3.2. State Energy Code Performance Estimates, Electricity (site kWh/ft^2-yr)

State	Electricity - HVAC STD2004	Electricity - HVAC STD2007	Electricity - HVAC STD2010	Electricity - Light/Other STD2004	Electricity - Light/Other STD2007	Electricity - Light/Other STD2010
Alabama	6.48	6.30	4.73	9.53	9.27	7.83
Alaska	5.12	4.92	3.68	9.83	9.49	8.21
Arizona	7.31	7.09	5.48	9.16	8.90	7.59
Arkansas	6.39	6.19	4.58	9.77	9.47	7.98
California	4.81	4.68	3.63	9.07	8.83	7.57
Colorado	4.51	4.37	3.30	9.57	9.29	8.00
Connecticut	4.82	4.65	3.54	9.54	9.24	7.94
Delaware	6.05	5.84	4.12	10.72	10.37	8.95
District of Columbia	3.60	3.55	2.72	8.37	8.27	7.25
Florida	7.25	7.03	5.31	9.19	8.93	7.59
Georgia	6.07	5.91	4.44	9.22	8.97	7.57
Hawaii	10.08	9.91	7.91	9.12	8.92	7.91
Idaho	4.93	4.75	3.38	10.26	9.92	8.41
Illinois	5.16	4.99	3.69	9.97	9.67	8.44
Indiana	4.94	4.79	3.56	9.40	9.16	7.85
Iowa	4.58	4.44	3.41	9.56	9.31	7.88
Kansas	5.61	5.42	3.95	9.91	9.60	8.09
Kentucky	5.37	5.20	3.78	9.93	9.64	8.12
Louisiana	7.51	7.27	5.44	9.75	9.46	8.07
Maine	4.67	4.48	3.38	10.04	9.67	8.31
Maryland	4.73	4.60	3.40	9.16	8.94	7.68
Massachusetts	4.79	4.63	3.56	9.58	9.30	7.98
Michigan	5.02	4.83	3.63	10.11	9.76	8.26
Minnesota	4.77	4.62	3.48	9.81	9.53	8.36
Mississippi	7.22	7.02	5.28	9.89	9.63	8.25
Missouri	5.70	5.51	3.96	10.08	9.76	8.35
Montana	5.07	4.87	3.55	9.97	9.63	8.28
Nebraska	5.66	5.51	4.08	10.63	10.36	8.94
Nevada	5.91	5.77	4.54	9.72	9.48	8.29
New Hampshire	6.10	5.85	4.23	10.89	10.47	9.10
New Jersey	5.57	5.44	4.13	9.96	9.71	8.56
New Mexico	5.40	5.24	3.92	10.13	9.85	8.33
New York	4.27	4.16	3.37	8.94	8.73	7.85
North Carolina	5.96	5.78	4.27	9.66	9.38	8.03
North Dakota	5.65	5.46	4.08	10.33	10.03	8.70
Ohio	4.79	4.64	3.52	9.75	9.49	8.04
Oklahoma	6.56	6.36	4.66	9.85	9.58	8.10
Oregon	3.68	3.57	2.67	9.27	9.02	7.74
Pennsylvania	4.94	4.79	3.63	9.51	9.25	7.86
Rhode Island	4.37	4.18	3.18	8.99	8.64	7.14
South Carolina	5.72	5.51	3.99	9.20	8.89	7.44
South Dakota	4.42	4.30	3.36	9.90	9.64	8.20
Tennessee	5.78	5.61	4.12	9.70	9.44	8.08
Texas	6.74	6.56	4.91	9.36	9.12	7.77
Utah	3.75	3.62	2.76	8.85	8.59	7.23
Vermont	5.00	4.85	3.77	9.50	9.23	8.15
Virginia	5.41	5.27	3.93	9.63	9.38	8.15
Washington	3.81	3.70	2.75	9.30	9.05	7.82
West Virginia	5.11	4.95	3.84	9.95	9.63	8.05
Wisconsin	4.85	4.70	3.48	9.60	9.34	8.24
Wyoming	4.17	4.06	3.29	9.85	9.61	8.13

Table 3.3. State Energy Code Performance Estimates, Natural Gas (kBtu/ft^2-yr)

State	Natural Gas - HVAC			Natural Gas - Light/Other		
	STD2004	STD2007	STD2010	STD2004	STD2007	STD2010
Alabama	9.66	8.95	5.35	10.21	9.57	9.57
Alaska	42.64	39.49	27.82	14.41	13.56	13.55
Arizona	4.89	4.64	3.29	8.75	8.28	8.28
Arkansas	10.46	9.62	5.24	8.19	7.62	7.62
California	5.80	5.50	3.99	8.25	7.74	7.74
Colorado	15.69	14.66	11.87	9.73	9.22	9.21
Connecticut	23.26	21.58	14.70	9.77	9.20	9.20
Delaware	20.09	18.66	10.33	6.43	6.06	6.05
District of Columbia	11.38	10.08	6.28	4.97	4.60	4.59
Florida	6.10	5.76	3.66	7.65	7.22	7.21
Georgia	9.79	9.04	5.35	10.29	9.61	9.61
Hawaii	2.56	2.44	1.38	13.99	13.15	13.14
Idaho	17.63	16.35	13.15	8.81	8.32	8.31
Illinois	24.76	23.11	14.77	6.38	6.02	6.02
Indiana	23.24	22.05	15.05	10.21	9.70	9.69
Iowa	22.64	20.90	12.67	8.39	7.86	7.85
Kansas	17.13	15.76	8.53	8.74	8.16	8.16
Kentucky	17.17	16.04	9.41	7.90	7.50	7.50
Louisiana	7.95	7.48	4.64	9.55	9.00	9.00
Maine	29.12	26.68	16.85	11.24	10.54	10.54
Maryland	14.77	13.73	8.47	6.68	6.31	6.31
Massachusetts	22.04	20.40	13.32	7.23	6.81	6.81
Michigan	24.47	22.53	14.76	9.68	9.13	9.13
Minnesota	27.68	25.71	16.65	6.71	6.32	6.31
Mississippi	9.77	9.14	5.30	11.40	10.71	10.70
Missouri	18.20	16.90	9.62	7.78	7.33	7.33
Montana	21.61	19.99	13.47	11.69	11.00	10.99
Nebraska	24.99	23.28	13.94	9.95	9.36	9.35
Nevada	7.32	6.85	5.12	14.15	13.32	13.32
New Hampshire	28.86	26.59	17.71	10.29	9.70	9.69
New Jersey	21.44	19.98	11.94	14.41	13.56	13.55
New Mexico	10.59	9.88	7.59	11.09	10.39	10.38
New York	17.45	16.11	10.48	8.35	7.85	7.85
North Carolina	14.15	13.15	7.69	10.35	9.73	9.72
North Dakota	30.10	28.23	19.49	10.54	9.98	9.98
Ohio	23.21	21.54	13.21	8.76	8.22	8.22
Oklahoma	10.68	9.99	6.16	10.36	9.75	9.75
Oregon	13.91	13.07	9.37	9.47	8.89	8.89
Pennsylvania	22.40	20.74	13.10	11.42	10.70	10.69
Rhode Island	17.74	16.09	10.92	5.08	4.77	4.77
South Carolina	9.15	8.49	5.35	7.46	7.00	7.00
South Dakota	29.25	26.98	16.24	11.47	10.75	10.75
Tennessee	16.70	15.64	9.45	9.98	9.39	9.39
Texas	8.21	7.71	4.73	8.80	8.26	8.25
Utah	13.82	12.79	10.65	7.25	6.82	6.81
Vermont	28.37	26.47	18.52	16.88	15.87	15.86
Virginia	17.22	15.96	9.15	11.55	10.85	10.85
Washington	12.98	12.20	8.91	8.44	7.96	7.95
West Virginia	20.28	18.36	11.09	10.78	10.08	10.07
Wisconsin	29.24	27.59	18.76	10.27	9.71	9.70
Wyoming	22.72	20.66	12.15	14.07	13.10	13.10

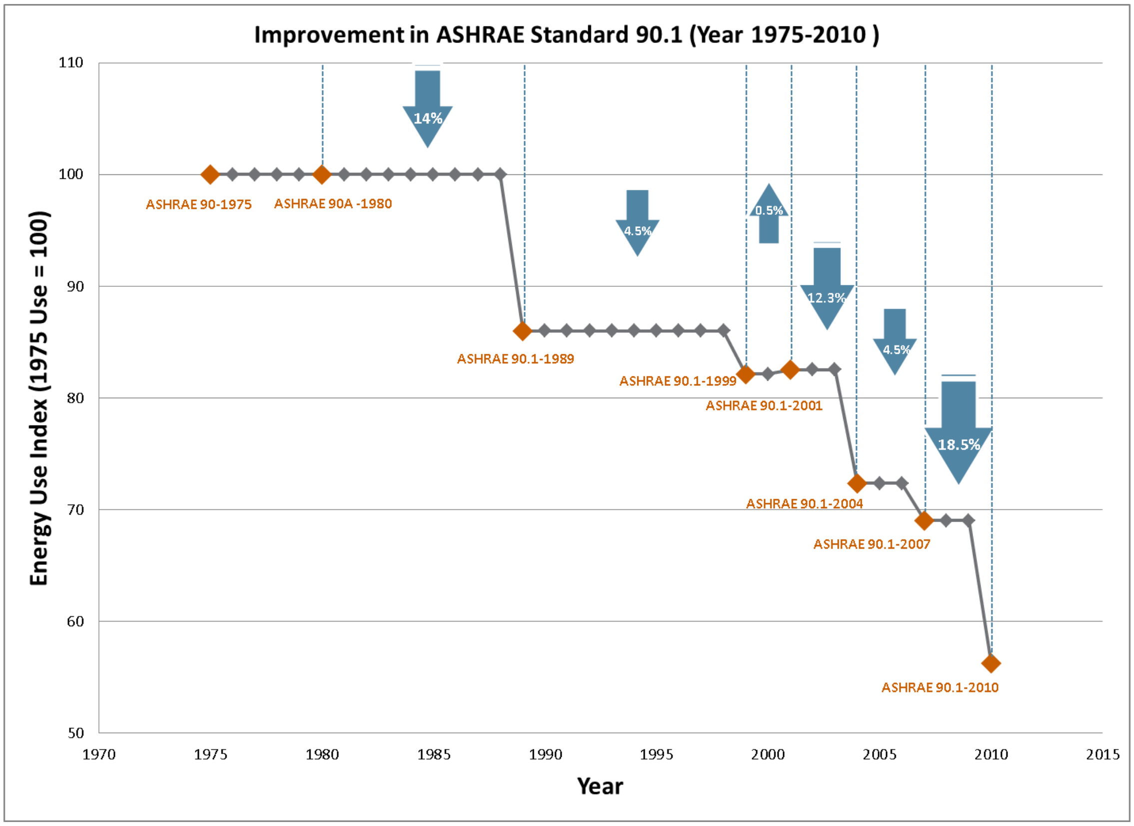

Figure 3.1. ASHRAE Standard 90.1 Improvement Index

3.2 Commercial Floor Space Forecast

Calculating the floor area attributable to new commercial buildings and additions to and renovations of existing commercial buildings is integral to the analysis of energy codes because the potential energy savings are estimated on the basis of gross floor area. However, there are no publicly available sources of these data for commercial buildings on a state-by-state basis. A further complication is that energy codes and standards apply not only to new floor area, but also to the floor area associated with additions to and renovations of existing buildings. The estimation of the code-applicable floor space is discussed in detail below.

Three sets of estimates, historical floor space, new floor space, and alterations, were combined to form one time-series floor space projection, in terms of millions of square feet that accounted for the space associated with both newly-constructed buildings and additions to existing buildings that is subject to the commercial energy codes and standards.

3.2.1 Historical Data for New Construction and Additions to Existing Buildings

For the years 1992–2002, the U.S. Census Statistical Abstract provides state-level value of construction contracts data. For the years 2003–2010, construction contract data from MHC-Dodge were obtained. These data include valuations and floor space associated with new construction and additions to existing buildings, as well as valuations (only) for alterations of existing space.

Several steps were taken to develop a consistent time-series of incremental commercial floor space subject to energy codes from 1992–2010:

1. The census data were converted from valuations to floor space by applying a state-specific ratio representing 2003–2007 Dodge floor space added (for new construction and additions) per $1,000 of construction value. The census data included valuations not only for commercial new construction and additions, but also for alterations and manufacturing. However, the application of this MHC-Dodge-based ratio effectively yielded floor space only for commercial new construction and additions, under the implicit assumption that the portions of census data that represent alterations and manufacturing remain constant over time.
2. The resulting 1992–2010, each state-level time series was then scaled by a multiplicative factor (scalar) so that their sum matched the reported national annual added floor space totals in the Census Statistical Abstract. This latter step corrected for lower construction costs prior to the 2003–2007 period associated with the multiplied MHC-Dodge-based ratio.

Two more adjustments were made to the resulting data:

1. A global scalar of 1.2 was applied to the state-level results. This scalar adjusted for underreporting and more closely matched floor space reported by the Energy Information Administration's (EIA's) Commercial Buildings Energy Consumption Survey (CBECS) (EIA 2006). The growth in commercial floor space was analyzed using the national floor area square footage data by year from MHC-Dodge in a spreadsheet model. While MHC-Dodge is a valuable source for measuring the amount of new floor area additions, it does not cover all new commercial building projects in the United States. MHC-Dodge does not cover smaller projects costing less than $100,000, and other projects are not captured simply because they are not put out for bid by building contractors.

   To account for this "undercoverage," the spreadsheet model was calibrated using a floor area survival function to yield similar growth rates in total U.S. commercial building floor space, as reported in various editions of the CBECS. As part of this calibration, the MHC-Dodge figures for total construction were factored up by 20% to account for underreporting of the smaller projects.[4] While underreporting is likely to vary across states, there are no data to support differential adjustment factors by state; thus, the 20% factor was applied uniformly across all states.
2. Given that both the MHC-Dodge data and the Census Statistical Abstract data represent contracts to build rather than delivered space, lag factors were applied to the data. The lagged data were used as the proxy for the historical floor space completions.

[4] This adjustment is similar to that used by the Census Bureau to estimate private nonresidential construction in the United States. The Census Bureau adjusts data from MHC-Dodge upward by 25% to account for undercoverage of projects. (See the methodology description at http://www.census.gov/const/www/methodpage.html.) The smaller adjustment factor in the current analysis provides a better calibration with the published floor space data in EIA's CBECS**.**

3.2.2 Projected Data for New Construction and Additions to Existing Buildings

To project floor space through 2040, the census and MHC-Dodge data, which covered the period through 2010, was combined with the EIA's Annual Energy Outlook (AEO) 2012 (DOE/EIA 2012), which provided the additional data through 2040. The AEO 2012 Reference Case forecasts commercial floor space added by year and by the nine census divisions. However, these floor space estimates were not utilized directly. Rather, the census division and year-specific growth rates implicit in the AEO floor space forecast were applied to the previously developed historical data.

The AEO forecast did not integrate seamlessly with the historical data, at least partially due to the substantial and prolonged impacts of the economic downturn in the roughly 2008−2011 timeframe. The MHC-Dodge-based historical data show a much deeper contraction than the AEO 2012 data. As a result, AEO 2012 growth rates, when applied to the 2010 historical data, would yield an unrealistically low long-term forecast of commercial floor space. To adjust for that, AEO growth rates were applied to an average of the 2006–2010 historical data, representing a more normal construction volume and higher base value for the forecast, rather than simply extrapolating from the 2010 data.

Although applying the AEO growth rates to a higher base floor space value remedied the issue of an unrealistically low forecast in the long-term, it also created an apparent short-term spike in the forecast. As a result, the scaling factors in Table 3.4 were applied to the floor space results for the years 2011–2014 to provide a more realistic transition from the depressed construction levels of 2010.

Table 3.4. Scaling Factors

Year	Scaling Factor
2011	0.6306
2012	0.6203
2013	0.7544
2014	0.9011

The resulting AEO-derived data for the years 2011–2040 are at the census division level. To apportion the census division estimates to the state level, MHC-Dodge-based 2006–2010 state shares were applied to each census division. The purpose of using a multi-year state average to smooth shares was to avoid the distortions created by the economic downturn. Several states' shares within their respective census divisions deviated dramatically from historical norms near the construction industry's trough, with Nevada in 2010 being a key example. The resulting smoothed state-level data for 2011–2040 were combined with the 1992–2010 data.

3.2.3 Alterations

New construction and additions to existing buildings are not the only means by which building energy codes may provide energy savings. Alterations of existing space in buildings may also be subject to the codes. To incorporate alterations to existing space, the analysis used state-specific alterations ratios, in combination with a renovation fraction[5]:

- The period 2003–2007 was chosen to represent a period free from the distortions of the subsequent recession.
- This period was used to calculate the alterations ratios, which are the ratios of the average annual valuation of alterations to the average annual valuation of new construction and additions to existing buildings. The purchased MHC-Dodge data provided the necessary values.
- The products of the state-specific alterations ratios and the renovation fraction were multiplied by the state-level, annual floor space data associated with new construction plus additions, for the years 1992–2040. This product yields estimates of state-level, annual altered floor space subject to energy codes.
- A key assumption associated with this method is that the per-square foot cost of an energy-code-impacting alteration across all relevant alteration types is on average close to the cost of newly-added or constructed space.

The three sets of estimates combined (adjusted historical data, new floor space forecast, and alterations) resulted in a floor space projection, in terms of millions of square feet, that accounted for the space associated with both newly-constructed buildings and additions to existing buildings that is subject to the commercial energy codes and standards.

3.3 Adoption of Commercial Energy Codes and Standards

The adoption of model codes presents a significant opportunity to save energy in residential and commercial buildings. The United States does not have a national energy code or standard, so energy codes are adopted at the state and local levels of government. Through the BECP, DOE provides technical assistance to state and local governments to help facilitate the acceleration of model energy codes adoption. The analysis aimed to estimate the impact of BECP activities and DOE's influence on accelerating the rate of adoption of codes and standards and/or their adoption effective date.[6]

Three types of adoption rate assumptions were used in the impact analysis to develop two scenarios ("with BECP" and "without BECP"):

1. Historical Explicit – adoption rates when a state explicitly adopts an energy code.
2. Historical Implicit – adoption rates where states do not explicitly adopt an energy code, but the building practices are nevertheless changing under influence from within the state or surrounding states.

[5] The renovation fraction is the fraction of renovation (by dollar value) that is assumed to be subject to the new energy code. In other words, this is the fraction of renovations that impact energy-related features of the space. Such features may include HVAC, envelope, and lighting. The renovation fraction was assumed to be 0.7, the value used in past analyses and based on professional judgment.

[6] It is generally the case that there are two different dates associated with an energy code or standard. One is the date of adoption; that is when the document is officially "placed on the books." The other is the effective date; that is, the date when all commercial buildings are required to comply with what is adopted. Both are critical to energy savings, but the savings do not technically start to accrue until the adopted document becomes effective and required.

3. Future Adoption – states are divided into three categories (aggressive, moderate, slow) based on historical energy code adoption patterns, their respective regulatory review cycle, and legislative activity. Future adoption years are projected based on each state's applicable category.

3.3.1 Historical Explicit Adoption Rate Assumptions

Currently, 44 states have adopted some form of a statewide commercial building energy code. In the remaining states, local municipalities and/or counties within those states are not precluded from adopting local building energy codes. BECP recognizes that in all cases, the energy code is effectively implemented at the local jurisdiction level (county or city) where building construction and permitting take place. For the purposes of this analysis, status of adoption was characterized at the state level. Status of local jurisdictional adoption was not considered due to a lack of supporting data.

Because states typically adopt the International Energy Conservation Code (IECC) and then by reference in the IECC automatically get Standard 90.1, the adoption assumption tables show the adopted versions of the IECC and reference versions of Standard 90.1.

From 1992 until the publication of Standard 90.1-1999/2001, the BECP's impact was attributable primarily to efforts to accelerate the adoption of Standard 90.1-1989 or model energy codes based on the standard and to provide materials to improve compliance with Standard 90.1-1989. Starting with Standard 90.1-2004, energy savings are also attributable to DOE efforts to improve the energy efficiency of Standard 90.1 as states updated to Standards 90.1-2004 and 90.1-2007 or associated versions of the IECC.

The years when states started receiving credit for savings induced by adopting the corresponding version of the code are presented in Table 3.5. The dates in the table are not actual adoption years, but rather show the first year when the code comes into effect and the state can be credited for the savings. July is the cutoff point for crediting the states with savings for the newly adopted code in a given year. The cutoff point is consistent with the assumption that there is typically at least a 6-month lag between the issuance of the permit and commissioning of the building. Therefore, if the code becomes effective during July or after, the construction that follows will not typically be complete in time for savings to occur in that calendar year.

Table 3.5. Start Year for Crediting States with Commercial Energy Code Savings Based on the Newly Adopted Code

State	MEC 92-95 90.1-1989	IECC 2000/2003, 90.1-1999/2001	IECC 2006 90.1-2004	IECC 2009 90.1-2007	IECC 2012 90.1-2010
Alabama				2013	
Alaska					
Arizona					
Arkansas	1995	2005		2013	
California	1992	2001	2006	2010	
Colorado		2005	2008		
Connecticut	1990	2005	2009	2012	
Delaware	1996	2004		2010	
District of Columbia	2000	2004		2010	
Florida	1993		2005	2012	

Table 3.5. (contd)

State	MEC 92-95 90.1-1989	IECC 2000/2003, 90.1-1999/2001	IECC 2006 90.1-2004	IECC 2009 90.1-2007	IECC 2012 90.1-2010
Georgia	1996	2003	2008	2011	
Hawaii	1995	2004	2010		
Idaho		2005	2008	2011	
Illinois		2006	2008	2010	2013
Indiana	1993			2010	
Iowa	1993	2004	2007	2010	
Kansas					
Kentucky		2005	2007	2011	
Louisiana	1999	2005	2007	2011	
Maine	1990	2000	2005	2011	
Maryland	1997	2005	2007	2010	2012
Massachusetts	1992	2001	2008	2010	
Michigan		2009		2011	
Minnesota	1999		2009		
Mississippi					2013
Missouri					
Montana	1996	2005		2010	
Nebraska		2005		2012	
Nevada		2005	2010	2012	
New Hampshire	1999	2002	2007	2010	
New Jersey	1997	2002	2007	2011	
New Mexico		2004	2008	2012	
New York	1991	2002	2008	2011	
North Carolina	1996	2006	2009	2012	
North Dakota				2011	
Ohio	1995	2005	2008	2012	
Oklahoma			2011		
Oregon	1993	2001	2007	2010	
Pennsylvania		2004	2007	2010	
Rhode Island	1997	2004	2007	2010	
South Carolina	1997	2005	2008	2013	
South Dakota					
Tennessee			2011		
Texas		2001		2011	
Utah	1995	2002	2007	2010	
Vermont	1996	2001	2007	2012	
Virginia	1997	2004	2006	2011	
Washington	1994	2002	2005	2011	2013
West Virginia	2003	2010		2012	
Wisconsin	1997		2008	2012	
Wyoming					

3.3.2 Historical Implicit Adoption Assumptions

Although some states have not yet adopted any statewide energy code applicable to commercial buildings, it is unreasonable to believe that common building practice in these states remains at the level of Standard 90A-1980. Building efficiency has improved nationwide because of more cost-effective technologies (e.g., electronic ballasts and T-8 lamps) and the transfer of knowledge of efficient construction practices from states with building energy codes. The use of national or regional architect-engineering firms in states with building energy codes influences the level of common practice in other states—a process characterized as a "spillover" effect. Some spillover is simply due to market forces, but it also could be driven by the adoption of energy codes in other states. Spillover is also driven by corporations that have properties in multiple states (hotels, retail stores, etc.) that have standardized designs and typically meet the more stringent energy and buildings standards in their market. Hence, it can be argued that the BECP has indirectly influenced new building efficiency in these states as well, even if the influence is difficult to quantify.

To recognize that building practices in all states will eventually meet a given historical code level, the approach in this analysis incorporated the notion of an "implicit" adoption. For the historical scenario ("with BECP"), the analysis assumed that the efficiency levels implied by Standard 90.1-1989, even in states and jurisdictions without a mandatory energy code, were reached by the late 1990s at the latest. For the 1999 and later versions of the ASHRAE standard, this time lag was assumed to be 10 years.

If a state skips one or more code cycles and then explicitly adopts a code version, then for the skipped code versions the credit starts either in the implicit adoption year, or the year when the later code version was explicitly adopted, whichever comes first. For example: North Dakota adopted the IECC 2009 (ICC 2009) in 2011. Thus, for IECC 2006 (ICC 2006) we show 2011, which is the lesser of the implicit adoption year (2016) and the explicit adoption year for the next code version (2011).

The code versions with a very small difference in EUIs were combined together for the analysis purposes. For example, the 2000 and 2003 versions of the IECC (ICC 2000; ICC 2003) did not have a significant difference in energy efficiency requirements (similar to Standards 90.1-1999 and 90.1-2001). For these combined code versions, the 10-year lag is added to the publication year of the first version in the combination. For example, the implicit adoption year for the 2000/2003 IECC in Alaska is 2010, not 2013.

In reality, knowledge spillover related to energy codes is gradual, with some practices and technologies likely to be used in states without codes soon after a code has been adopted in a neighboring state. Spillover would accelerate as more states adopt codes and regional design and construction firms carry over efficiency measures to projects in states without codes (or without the most recent national model code). This analysis did not incorporate the gradual nature of this process because of a lack of data to justify selection of any particular smoothing method; rather, it assumed a sudden, 1-year transition to the newer, more energy-efficient practices (code level) once states met the 10-year threshold.

Table 3.6 shows the start of the savings stream for both explicit and implicit adoption years. Implicit adoption years are highlighted in orange.

Table 3.6. Explicit and Implicit Adoption Years by State and Commercial Code

State	MEC 92-95 90.1-1989	IECC 2000/2003, 90.1-1999/2001	IECC 2006 90.1-2004	IECC 2009 90.1-2007	IECC 2012 90.1-2010
Alabama	2002	2010	2013	2013	
Alaska	2002	2010	2016		
Arizona	2002	2010	2016		
Arkansas	1995	2005	2013	2013	
California	1992	2001	2006	2010	
Colorado	2002	2005	2008		
Connecticut	1990	2005	2009	2012	

Table 3.6. (contd)

State	MEC 92-95 90.1-1989	IECC 2000/2003, 90.1-1999/2001	IECC 2006 90.1-2004	IECC 2009 90.1-2007	IECC 2012 90.1-2010
Delaware	1996	2004	2010	2010	
District of Columbia	2000	2004	2010	2010	
Florida	1993	2005	2005	2012	
Georgia	1996	2003	2008	2011	
Hawaii	1995	2004	2010		
Idaho	2002	2005	2008	2011	
Illinois	2002	2006	2008	2010	2013
Indiana	1993	2010	2010	2010	
Iowa	1993	2004	2007	2010	
Kansas	2002	2010	2016		
Kentucky	2002	2005	2007	2011	
Louisiana	1999	2005	2007	2011	
Maine	1990	2000	2005	2011	
Maryland	1997	2005	2007	2010	2012
Massachusetts	1992	2001	2008	2010	
Michigan	2002	2009	2011	2011	
Minnesota	1999	2009	2009		
Mississippi	2002	2010	2013	2013	2013
Missouri	2002	2010	2016		
Montana	1996	2005	2010	2010	
Nebraska	2002	2005	2012	2012	
Nevada	2002	2005	2010	2012	
New Hampshire	1999	2002	2007	2010	
New Jersey	1997	2002	2007	2011	
New Mexico	2002	2004	2008	2012	
New York	1991	2002	2008	2011	
North Carolina	1996	2006	2009	2012	
North Dakota	2002	2010	2011	2011	
Ohio	1995	2005	2008	2012	
Oklahoma	2002	2010	2011		
Oregon	1993	2001	2007	2010	
Pennsylvania	2002	2004	2007	2010	
Rhode Island	1997	2004	2007	2010	
South Carolina	1997	2005	2008	2013	
South Dakota	2002	2010	2016		
Tennessee	2002	2010	2011		
Texas	2001	2001	2011	2011	
Utah	1995	2002	2007	2010	
Vermont	1996	2001	2007	2012	
Virginia	1997	2004	2006	2011	
Washington	1994	2002	2005	2011	2013
West Virginia	2003	2010	2012	2012	
Wisconsin	1997	2008	2008	2012	
Wyoming	2002	2010	2016		

3.3.3 Future Adoption Assumptions

The first step in projecting future code adoption was to categorize the states based on historical explicit adoption behavior and existing practices. Each category was then assigned a discrete period of years representing the lag between the code version year and adoption year in order to forecast future code adoption for this analysis. Each state was assigned to one of three categories:

1. A = Aggressive; a state that consistently adopts the most recent published code OR within 1–3 years of published code (a gap = ≤ 3 years)

Example: Maryland has consistently adopted the most recent published codes over the past decade. The last adoption (of the 2012 IECC) occurred in 2012. Maryland is considered aggressive (adoption < 3 years of published code).

Assumption of future adoption = 1 year is added after published code

2. M = Moderate; a state that skips one published code cycle OR exceeds 3 years but less than 6 years between adoption (a gap = >3 years and ≤ 6 years)

Example: Idaho adopted the 2009 IECC in 2010 and plans to adopt the 2012 IECC in 2015 or later. Idaho exceeds 3 years since previous adoption but not greater than 6 years.

Assumption of future adoption = 4 years are added after published code

3. S = Slow; a state that skips more than one published code OR exceeds (in years) two published codes (a gap > 6 years) OR a state without any statewide adoption

Example: Arkansas is categorized as slow, with an 8-year gap between adoptions even though it adopted Standard 90.1-2007/2009 IECC in 2013. Arkansas' adoption history assumes a long gap before the next adoption.

Assumption of future adoption = 7 years are added after published code

State classifications and future adoption lag are presented in Table 3.7. There are six states whose classification varies between residential and commercial: Kentucky, Louisiana, Utah, Vermont, Virginia, and Wisconsin.

Table 3.7. State Classification for Future Commercial Energy Code Adoption

Aggressive (code version year +1 year)	**Moderate** (code version year +4 years)	**Slow** (code version year +7 years)
California	Connecticut	Alabama
Florida	Delaware	Alaska
Georgia	District of Columbia	Arizona
Illinois	Idaho	Arkansas
Iowa	Kentucky	Colorado
Maryland	Louisiana	Hawaii
Massachusetts	Maine	Indiana
New Hampshire	Michigan	Kansas
New York	Montana	Minnesota
North Carolina	Nebraska	Mississippi

Table 3.7. (contd)

Aggressive (code version year +1 year)	Moderate (code version year +4 years)	Slow (code version year +7 years)
Oregon	Nevada	Missouri
Rhode Island	New Jersey	North Dakota
Utah	New Mexico	Oklahoma
Washington	Ohio	South Dakota
	Pennsylvania	Tennessee
	South Carolina	West Virginia
	Texas	Wyoming
	Vermont	
	Virginia	
	Wisconsin	

3.3.4 Adoption Assumptions for the Counterfactual (without BECP) Scenario

This analysis assumed that DOE efforts accelerated the adoption of the most recently published model energy code or standard (or equivalent). That is, with a favorable political and fiscal climate, some states would generally adopt an updated model code or standard within a few years without federal assistance.[7]

A more difficult issue is how to attribute benefits from the spillover process to the BECP. Because the analysis assumed that adoption occurs all at once in a state in a single year, the calculation methodology did not account for spillover effects from other states for the state undergoing adoption in that year. However, the implicit adoption of codes is accelerated as a result of national codes and standards development and deployment activities. Without the DOE activities, the spillover effect in states without a statewide code would have occurred at a slower rate; therefore, implicit adoption would have been delayed as well.

To develop effective adoption year estimates for the counterfactual analysis, each category of states was assigned a discrete period of years. This was intended to capture the BECP influence on accelerating the adoption of: a) an updated energy code or standard where one existed, or b) a new energy code or standard where one did not previously exist. To stay consistent with the state groupings for future code adoption, three sets of lags were used to describe how adoption would likely evolve without BECP:

- For states with aggressive future adoption, one more year was added to the effective adoption year in the “with BECP” scenario.
- For states with moderate future adoption, a lag of 6 years was added to the “with BECP” adoption year.
- For states with a slow adoption rate, only 3 years were added to the “with BECP” adoption year.

A full set of adoption assumptions for both scenarios (with and without BECP) is included in Table 3.8 and Table 3.9. Projected adoption years are highlighted in grey.

[7] This is typical for cases where the energy code is a component of an entire building regulatory package that includes building, fire, electrical, mechanical, plumbing, and other codes that are adopted on a regular 3-year cycle, generally 12 to 18 months after their publication by the organization publishing those codes.

Table 3.8. Commercial Energy Code Adoption Assumptions for Scenario “with BECP”

		MEC 92-95, 90.1-1989	IECC 2000/2003, 90.1-1999/2001	IECC 2006 90.1-2004	IECC 2009 90.1-2007	IECC 2012 90.1-2010	IECC 2015 90.1-2013	IECC 2018 90.1-2016	IECC 2021 90.1-2019	IECC 2024 90.1-2022	IECC 2027 90.1-2025
S	Alabama	2002	2010	2013	2013	2019	2022	2025	2028	2031	2034
S	Alaska	2002	2010	2016	2016	2019	2022	2025	2028	2031	2034
S	Arizona	2002	2010	2016	2016	2019	2022	2025	2028	2031	2034
S	Arkansas	1995	2005	2013	2013	2019	2022	2025	2028	2031	2034
A	California	1992	2001	2006	2010	2013	2016	2019	2022	2025	2028
S	Colorado	2002	2005	2008	2016	2019	2022	2025	2028	2031	2034
M	Connecticut	1990	2005	2009	2012	2016	2019	2022	2025	2028	2031
M	Delaware	1996	2004	2010	2010	2016	2019	2022	2025	2028	2031
M	District of Columbia	2000	2004	2010	2010	2016	2019	2022	2025	2028	2031
A	Florida	1993	2005	2005	2012	2013	2016	2019	2022	2025	2028
A	Georgia	1996	2003	2008	2011	2013	2016	2019	2022	2025	2028
S	Hawaii	1995	2004	2010	2016	2019	2022	2025	2028	2031	2034
M	Idaho	2002	2005	2008	2011	2016	2019	2022	2025	2028	2031
A	Illinois	2002	2006	2008	2010	2013	2016	2019	2022	2025	2028
S	Indiana	1993	2010	2010	2010	2019	2022	2025	2028	2031	2034
A	Iowa	1993	2004	2007	2010	2013	2016	2019	2022	2025	2028
S	Kansas	2002	2010	2016	2016	2019	2022	2025	2028	2031	2034
M	Kentucky	2002	2005	2007	2011	2016	2019	2022	2025	2028	2031
M	Louisiana	1999	2005	2007	2011	2016	2019	2022	2025	2028	2031
M	Maine	1990	2000	2005	2011	2016	2019	2022	2025	2028	2031
A	Maryland	1997	2005	2007	2010	2012	2016	2019	2022	2025	2028
A	Massachusetts	1992	2001	2008	2010	2013	2016	2019	2022	2025	2028
M	Michigan	2002	2009	2011	2011	2016	2019	2022	2025	2028	2031
S	Minnesota	1999	2009	2009	2016	2019	2022	2025	2028	2031	2034
S	Mississippi	2002	2010	2013	2013	2013	2022	2025	2028	2031	2034
S	Missouri	2002	2010	2016	2016	2019	2022	2025	2028	2031	2034
M	Montana	1996	2005	2010	2010	2016	2019	2022	2025	2028	2031
M	Nebraska	2002	2005	2012	2012	2016	2019	2022	2025	2028	2031
M	Nevada	2002	2005	2010	2012	2016	2019	2022	2025	2028	2031
A	New Hampshire	1999	2002	2007	2010	2013	2016	2019	2022	2025	2028
M	New Jersey	1997	2002	2007	2011	2016	2019	2022	2025	2028	2031
M	New Mexico	2002	2004	2008	2012	2016	2019	2022	2025	2028	2031
A	New York	1991	2002	2008	2011	2013	2016	2019	2022	2025	2028
A	North Carolina	1996	2006	2009	2012	2013	2016	2019	2022	2025	2028
S	North Dakota	2002	2010	2011	2011	2019	2022	2025	2028	2031	2034
M	Ohio	1995	2005	2008	2012	2016	2019	2022	2025	2028	2031
S	Oklahoma	2002	2010	2011	2016	2019	2022	2025	2028	2031	2034
A	Oregon	1993	2001	2007	2010	2013	2016	2019	2022	2025	2028
M	Pennsylvania	2002	2004	2007	2010	2016	2019	2022	2025	2028	2031
A	Rhode Island	1997	2004	2007	2010	2013	2016	2019	2022	2025	2028
M	South Carolina	1997	2005	2008	2013	2016	2019	2022	2025	2028	2031
S	South Dakota	2002	2010	2016	2016	2019	2022	2025	2028	2031	2034
S	Tennessee	2002	2010	2011	2016	2019	2022	2025	2028	2031	2034
M	Texas	2001	2001	2011	2011	2016	2019	2022	2025	2028	2031
A	Utah	1995	2002	2007	2010	2013	2016	2019	2022	2025	2028
M	Vermont	1996	2001	2007	2012	2016	2019	2022	2025	2028	2031
M	Virginia	1997	2004	2006	2011	2016	2019	2022	2025	2028	2031
A	Washington	1994	2002	2005	2011	2013	2016	2019	2022	2025	2028
S	West Virginia	2003	2010	2012	2012	2019	2022	2025	2028	2031	2034
M	Wisconsin	1997	2008	2008	2012	2016	2019	2022	2025	2028	2031
S	Wyoming	2002	2010	2016	2016	2019	2022	2025	2028	2031	2034

State Classifications: A = Aggressive; M = Moderate; S = Slow

Table 3.9. Commercial Energy Code Adoption Assumptions for Scenario “without BECP”

		MEC 92-95 90.1-1989	IECC 2000/2003, 90.1-1999/2001	IECC 2006 90.1-2004	IECC 2009 90.1-2007	IECC 2012 90.1-2010	IECC 2015 90.1-2013	IECC 2018 90.1-2016	IECC 2021 90.1-2019	IECC 2024 90.1-2022	IECC 2027 90.1-2025
S	Alabama	2005	2013	2016	2016	2022	2025	2028	2031	2034	2037
S	Alaska	2005	2013	2019	2019	2022	2025	2028	2031	2034	2037
S	Arizona	2005	2013	2019	2019	2022	2025	2028	2031	2034	2037
S	Arkansas	1998	2008	2016	2016	2022	2025	2028	2031	2034	2037
A	California	1993	2002	2007	2011	2014	2017	2020	2023	2026	2029
S	Colorado	2005	2008	2011	2019	2022	2025	2028	2031	2034	2037
M	Connecticut	1996	2011	2015	2018	2022	2025	2028	2031	2034	2037
M	Delaware	2002	2010	2016	2016	2022	2025	2028	2031	2034	2037
M	District of Columbia	2006	2010	2016	2016	2022	2025	2028	2031	2034	2037
A	Florida	1994	2006	2006	2013	2014	2017	2020	2023	2026	2029
A	Georgia	1997	2004	2009	2012	2014	2017	2020	2023	2026	2029
S	Hawaii	1998	2007	2013	2019	2022	2025	2028	2031	2034	2037
M	Idaho	2008	2011	2014	2017	2022	2025	2028	2031	2034	2037
A	Illinois	2003	2007	2009	2011	2014	2017	2020	2023	2026	2029
S	Indiana	1996	2013	2013	2013	2022	2025	2028	2031	2034	2037
A	Iowa	1994	2005	2008	2011	2014	2017	2020	2023	2026	2029
S	Kansas	2005	2013	2019	2019	2022	2025	2028	2031	2034	2037
M	Kentucky	2008	2011	2013	2017	2022	2025	2028	2031	2034	2037
M	Louisiana	2005	2011	2013	2017	2022	2025	2028	2031	2034	2037
M	Maine	1996	2006	2011	2017	2022	2025	2028	2031	2034	2037
A	Maryland	1998	2006	2008	2011	2013	2017	2020	2023	2026	2029
A	Massachusetts	1993	2002	2009	2011	2014	2017	2020	2023	2026	2029
M	Michigan	2008	2015	2017	2017	2022	2025	2028	2031	2034	2037
S	Minnesota	2002	2012	2012	2019	2022	2025	2028	2031	2034	2037
S	Mississippi	2005	2013	2016	2016	2016	2025	2028	2031	2034	2037
S	Missouri	2005	2013	2019	2019	2022	2025	2028	2031	2034	2037
M	Montana	2002	2011	2016	2016	2022	2025	2028	2031	2034	2037
M	Nebraska	2008	2011	2018	2018	2022	2025	2028	2031	2034	2037
M	Nevada	2008	2011	2016	2018	2022	2025	2028	2031	2034	2037
A	New Hampshire	2000	2003	2008	2011	2014	2017	2020	2023	2026	2029
M	New Jersey	2003	2008	2013	2017	2022	2025	2028	2031	2034	2037
M	New Mexico	2008	2010	2014	2018	2022	2025	2028	2031	2034	2037
A	New York	1992	2003	2009	2012	2014	2017	2020	2023	2026	2029
A	North Carolina	1997	2007	2010	2013	2014	2017	2020	2023	2026	2029
S	North Dakota	2005	2013	2014	2014	2022	2025	2028	2031	2034	2037
M	Ohio	2001	2011	2014	2018	2022	2025	2028	2031	2034	2037
S	Oklahoma	2005	2013	2014	2019	2022	2025	2028	2031	2034	2037
A	Oregon	1994	2002	2008	2011	2014	2017	2020	2023	2026	2029
M	Pennsylvania	2008	2010	2013	2016	2022	2025	2028	2031	2034	2037
A	Rhode Island	1998	2005	2008	2011	2014	2017	2020	2023	2026	2029
M	South Carolina	2003	2011	2014	2019	2022	2025	2028	2031	2034	2037
S	South Dakota	2005	2013	2019	2019	2022	2025	2028	2031	2034	2037
S	Tennessee	2005	2013	2014	2019	2022	2025	2028	2031	2034	2037
M	Texas	2007	2007	2017	2017	2022	2025	2028	2031	2034	2037
A	Utah	1996	2003	2008	2011	2014	2017	2020	2023	2026	2029
M	Vermont	2002	2007	2013	2018	2022	2025	2028	2031	2034	2037
M	Virginia	2003	2010	2012	2017	2022	2025	2028	2031	2034	2037
A	Washington	1995	2003	2006	2012	2014	2017	2020	2023	2026	2029
S	West Virginia	2006	2013	2015	2015	2022	2025	2028	2031	2034	2037
M	Wisconsin	2003	2014	2014	2018	2022	2025	2028	2031	2034	2037
S	Wyoming	2005	2013	2019	2019	2022	2025	2028	2031	2034	2037

State Classifications: A = Aggressive; M = Moderate; S = Slow

3.4 Code Compliance

Promoting greater compliance with building energy codes is an important element of the BECP. The BECP conducts activities designed to increase compliance with the existing (or pending) energy code adopted by a specific state or jurisdiction. Two aspects of compliance were considered in this analysis: a) legal compliance, which is defined as meeting all of the provisions of the code; and b) compliance in energy terms, which accounts for energy savings in buildings that only partially meet the requirements of the new energy code. Therefore, compliance in energy terms is defined as "current practice" or the percentage of the code-to-code energy savings achievable from constructing to the level of the prevailing energy code rather than the prior code. Similar to the method used for adoption, reasonable alternative scenarios had to be developed to analyze the difference in compliance levels (in the first year of the code as well as subsequent years), both in the presence and absence of the BECP. These alternative scenarios were developed based on the detailed review of several key commercial energy code compliance studies (DOE 2010).

Code training and knowledge of new codes contribute significantly to the success and implementation of energy codes and savings. Without training, most builders and code officials are unlikely to change their behavior, and training activities have been critical to disseminating the necessary information. The availability of compliance software and materials also increases the success of energy codes because these tools enable builders, designers, and code inspectors to assess the compliance of construction plans with building energy codes.

Another potential reason that new code requirements disseminate, especially in the commercial sector, is professional liability. Registered design professionals may be held to the "most current" design standards even if their state or local jurisdiction is using an outdated energy code. In addition, more progressive municipalities and builders could be expected to attempt to meet at least some of the more well-publicized requirements of the new code (e.g., references to newer lighting technologies) solely based on their awareness that a new code is in effect. In the analytical framework, this effect is modeled as an increase of code compliance over time.

The following logic was applied to developing compliance assumptions for this assessment. Even with BECP in place, legal compliance with all provisions of the new code was not assumed to occur in full, at least not in the first year or two following the adoption of the new code. However, BECP assistance with training, support materials, and software tools increases the rate of compliance in energy terms (i.e., the achieved fraction of nominal energy savings for all versions of ASHRAE Standard 90.1). In the absence of the BECP, the legal compliance rates would have been lower. Similarly, rates of compliance in energy terms would be lower in the absence of BECP. Both legal compliance and compliance in energy terms would increase even without the BECP, but at a slower rate.

If no training or software tools were available to support compliance with the revised code, the initial rate of compliance in energy terms was assumed to be about 20-30% lower than what is currently observed. This particular range was derived based on the review of recent compliance studies and the report by the American Council for an Energy-Efficient Economy (ACEEE) (Misuriello et al. 2012). This range serves as the estimate of improvement in compliance as a result of training, software support, technical assistance, and other programmatic activities. It also provided the basis for parameterizing compliance assumptions for the alternative scenario (without BECP).

As states become more experienced with building energy codes, the percentage of achieved energy savings is expected to increase for subsequent versions of the code, even without DOE involvement in code deployment and compliance support.

This logic is reflected in Table 3.10, which shows compliance assumptions for the "with BECP" scenario for each relevant version of Standard 90.1.

Table 3.10. Compliance Assumptions for Standard 90.1, "With BECP" Scenario

	(a) Initially Compliant Buildings	(b) Initially Non-compliant Buildings	(c) **Weighted Compliance, Initial (Energy Terms)**	(d) Compliant Buildings after 10 Years	(e) Non-compliant Buildings after 10 Years	(f) **Weighted Compliance, After 10 Years (Energy Terms)**
90.1-1989						
Compliance in legal terms	40%	60%		80%	20%	
Compliance in energy terms	1.0	0.5	**70%**	1.0	0.5	**90%**
90.1-1999						
Compliance in legal terms	40%	60%		80%	20%	
Compliance in energy terms	1.0	0.5	**70%**	1.0	0.5	**90%**
90.1-2004						
Compliance in legal terms	50%	50%		80%	20%	
Compliance in energy terms	1.0	0.5	**75%**	1.0	0.5	**90%**
90.1-2007, 90.1-2010 and future versions						
Compliance in legal terms	50%	50%		80%	20%	
Compliance in energy terms	1.0	0.5	**75%**	1.0	0.5	**90%**

(a) Compliance in legal terms: percent of new construction fully meeting provisions of code change.
(b) Compliance in energy terms: achieved fraction of nominal code-to-code energy savings in buildings that only partially meet the new code requirements (i.e., buildings that are noncompliant in legal terms).
Columns (c) and (f): Weighted average fraction of potential savings for both legally compliant and not legally compliant buildings.

For consistency with the end-use categorization in the code-to-code savings analysis, the HVAC end-use group includes heating, cooling, fan, pump, and heat rejection, while Lighting/Other includes interior and exterior lighting, plug and process load, service hot water, refrigeration, and generators. Compliance rates presented in the table above apply to all modeled end-use groups uniformly.

Examples follow to explain the compliance assumptions in Table 3.10. As previously noted, these alternative scenarios and assumptions were developed based on the detailed review of several key commercial energy code compliance studies. The table shows two compliance rates in bold for

Standard 90.1-1989: weighted initial compliance and weighted compliance in 10 years from code adoption. Initial weighted compliance for this code version, shown as 70%, was calculated as follows:

- Given the outreach, training, information dissemination activities, and code compliance software tools developed under DOE's BECP at the time, the initial rate of compliance in legal terms was 40%. This means that 40% of newly constructed buildings were assumed to fully comply with the new energy code provisions. This portion of the buildings achieved a 1.0 fraction of nominal code-to-code energy savings, i.e., the compliance in energy terms.
- The remaining portion of new commercial construction (60%) also achieved a fraction of the nominal code-to-code savings (0.5 shown in column b).
- Weighting the compliance in energy terms by the compliance in legal terms produced the initial weighted compliance rate of 70% with the BECP in place.

As the building community gains experience, even without formal training, technical assistance, software tools, or other BECP supporting activities, the legal compliance rate is expected to increase over time for a given code, but at a slower rate. BECP support accelerates improvement in compliance, but learning remains a significant contributing factor. These learning and spillover effects were accounted for by looking at legal compliance rates 10 years from code adoption. For Standard 90.1-1989, the weighted compliance rate in 10 years, shown as 90%, was calculated as follows:

- The legal compliance increases from 40% to 80% (i.e., over 10 years), the fraction of the newly constructed buildings fully compliant with the code was assumed to double for the earlier code versions.
- Compliance in energy terms remains the same (0.5 fraction of the nominal code-to-code savings is achieved by the partially-compliant buildings).
- The improvement in legal compliance brings the weighted-average compliance to 90%.

The compliance rate for each analysis year was calculated by using initial compliance and weighted compliance for the relevant code version as 10-year anchor points, and interpolating the intermediate compliance rate based on how many years the adopted code version was in place.

As previously stated, for the "with BECP" scenario, the compliance rates were assumed to be uniform across the United States. For the alternative scenario (without BECP), a set of compliance lags was developed consistent with the classification of states based on code practices and adoption climate. This assumption was structured this way for several reasons:

- For establishing the impact of the Program, it is not the absolute level of compliance that drives the assessment, but rather the relative difference incompliance rates between the two compared scenarios ("with BECP" and "without BECP").
- It is very difficult to compare absolute levels of compliance across the states based on any particular definition of compliance and compatible metric. Review of the available compliance studies revealed the issues preventing meaningful cross-comparison of even the most recent results. The principal issues are differences in definitions of compliance and methods to measure/assess its level, as well as the application of different compliance metrics.

- It was neither the intent nor the scope of this analysis to compare compliance rates at the state level. The objective was to estimate the aggregate, national energy savings induced by BECP activities. Therefore, it was more important for this analysis to focus on the difference in compliance attributable to programmatic activities, as opposed to providing a survey of compliance rates for each state across the nation.

The compliance climate is believed to be strongly correlated with the adoption rates and code practices in place. For the alternative scenario, compliance rates differ across states based on each state's adoption category. Also, the credit given to BECP for improving compliance with the older code versions is lower than the credit for improving compliance with the future code versions. The compliance difference between the "with BECP" and "without BECP" scenarios is presented in Table 3.11.

Table 3.11. Percent Point Difference between Commercial Compliance Levels "with BECP" and "without BECP"

	Before 90.1-2004, percentage points difference	**After 90.1-2004, percentage points difference**
Aggressive	5%	10%
Moderate	20%	30%
Slow	10%	20%

This structure of compliance assumptions is consistent with BECP focusing on the development of energy codes in the past, but switching towards improving compliance in the future.

Following the classifications described in Section 3.3.3, for the states with aggressive adoption rates, a smaller lag was assumed for adoption, and a smaller percentage point difference was assumed for compliance (5 and 10 percentage points, respectively). This means that under the alternative scenario ("without BECP"), for example, for Standard 90.1-1999/2001, weighted initial compliance and weighted compliance in 10 years will be 5 percentage points less than what is shown in Table 3.10. For Standard 90.1-2007, the compliance difference is 10 percentage points.

For the second group of states (with moderate adoption rates), it was assumed that without BECP's compliance-related activities, compliance would decrease by 20% from the values shown in Table 3.10 for the code versions prior to Standard 90.1-2004, and by 30% for the consecutive code versions.

For states with slow adoption rates, the compliance rates would be 10 percentage points less than what is assumed for the code versions prior to Standard 90.1-2004 and 20 percentage points less for the code versions that follow. The initial intent was to not credit BECP with any compliance-induced savings in these states. However, American Recovery and Reinvestment Act (ARRA 2009) funding to states is believed to have led to several states adopting and implementing more recent energy codes earlier than they might have done without support. Therefore, although only a modest improvement is observed in this group of states, that improvement has occurred under targeted BECP support.

3.5 Estimated Benefits of the BECP Commercial Activities

This analysis assumed that BECP commercial energy code efforts improve code-to-code energy efficiency by supporting code development, accelerate the adoption of the most recent commercial building energy codes and standards (or equivalent), and increase compliance with the code provisions. Note that energy savings achieved in California, Florida, Oregon, and Washington were totally or partially removed from the BECP benefits calculation as presented in Table 3.12.[8]

Table 3.12. States Excluded from the BECP Commercial Benefits Calculation

State	Commercial
California	All years excluded
Florida	All years excluded
Oregon	Excluded 1992–2010
Washington	Excluded 1992–2012

The analysis period included estimation of the historical (1992–2012) and projected benefits (2013–2040) of the BECP commercial energy code activities. Projected benefits included two segments of savings as illustrated in Figure 3.2: (1) energy savings that will occur in the future, attributable to the energy code activities and construction to those codes in the past (construction occurring before 2013 but savings continuing through 2040); and (2) future savings attributable to future energy code activities and future construction (after 2013). Discussion of the estimation results follows this structure.

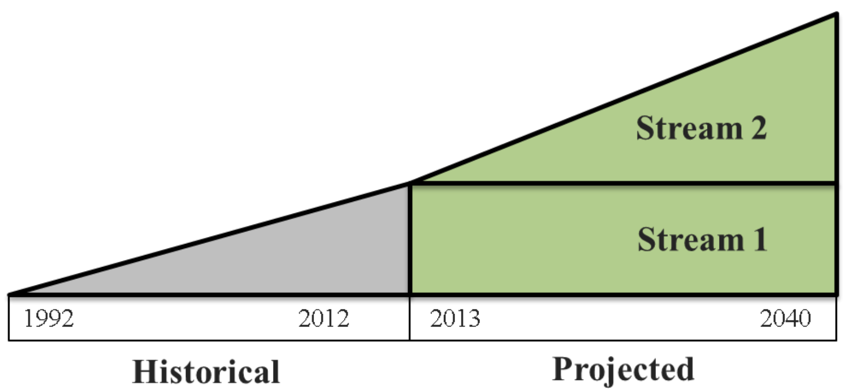

Figure 3.2. Historical and Projected Savings Streams

Following the analysis methodology used by DOE's Appliance and Equipment Standards Program, site energy savings were first converted to source terms, which includes energy used in generation, transmission, and distribution (primary energy). Energy used further "upstream" in the mining, processing, and transportation of fuels was calculated using the NIA PLUS model (Coughlin 2012)[9] and added to the primary energy savings to yield full-fuel-cycle (FFC) energy savings. Emissions savings and

[8] CA and FL have been excluded from this analysis due to their history of adopting their own advanced state-specific codes without direct assistance from BECP's tools or resources. WA and OR have been partially excluded due to their history of adopting their own state-specific codes without direct assistance from BECP's tools or resources, however, OR received state technical assistance to implement its state-specific code into COM*check* in 2010, and WA recently adopted a code based on the IECC.
[9] Coughlin, K., Calculation of Full Fuel Cycle Multipliers for Energy Use in Buildings. *LBNL Paper*, 2012.

emissions monetization were also calculated using the NIA PLUS model. Detailed explanations of technical assumptions, scalars, and cost rates underlying this set of calculations are available (10 CFR 429 and 430).

The remainder of this section discusses estimated site, primary, and FFC energy savings, emissions savings, emission monetization, and consumer benefits.

BECP historical and projected energy savings (site or delivered energy) are presented in Table 3.13. For the historical portion of the Program savings, cumulative site energy savings between 1992 and 2012 totaled 1,240 trillion British thermal units (TBtu), or about 1.2 quadrillion British thermal units (quads), with the annual site energy savings being approximately 151 TBtu at the end of 2012.

The amount of annual savings in 2012 (151 TBtu) from the pre-2012 construction continues from 2013 until 2040 because of the implicit assumption that the average expected lifetime of a commercial building exceeds the forecast horizon. This portion comprises the first stream of savings. Cumulative savings from this stream (not shown in the table) equal 4.2 quads in 2040.

Projected annual site savings from future code activities and construction equal 556 TBtu in 2040. Cumulative savings from this second savings stream equal 8.3 quads by 2040.

When the stream of future savings from past construction and the stream of future savings from future construction are combined, the annual projected savings equal 707 TBtu at the end of 2040. Cumulative site energy savings from commercial BECP activities for the period 1992 through 2010 reach 13.8 quads.

Table 3.13. BECP Commercial Site Energy Savings (TBtu)

	Electricity	Natural Gas	Total Annual Savings	Total Cumulative Savings	Post 2012 construction only Annual Site TBtu	Post 2012 construction only Cumulative Site TBtu
1992	0.3	0.2	0.6	0.6		
1993	0.8	0.6	1.4	2.0		
1994	1.3	0.9	2.2	4.1		
1995	2.5	1.6	4.2	8.3		
1996	4.5	2.6	7	15		
1997	7	3.9	11	26		
1998	9	5	15	41		
1999	13	7	20	61		
2000	16	9	26	86		
2001	22	12	34	120		
2002	31	16	47	167		
2003	38	20	57	224		
2004	45	23	69	293		
2005	52	27	79	372		
2006	61	31	91	463		
2007	69	35	104	567		
2008	78	40	117	684		
2009	84	43	127	812		
2010	89	45	134	946		
2011	94	49	143	1,089		
2012	100	52	151	1,240		
2013	108	56	164	1,404	13	13
2014	114	60	175	1,579	23	36
2015	122	65	187	1,766	36	72
2016	138	74	211	1,978	60	132
2017	151	82	232	2,210	81	213
2018	163	89	253	2,462	101	315
2019	183	100	283	2,745	131	446
2020	200	110	310	3,055	159	605
2021	218	120	338	3,393	187	792
2022	235	129	364	3,758	213	1,005
2023	251	138	389	4,146	237	1,242
2024	266	146	413	4,559	261	1,504
2025	281	154	435	4,994	283	1,787
2026	294	161	455	5,448	303	2,090
2027	307	167	474	5,923	323	2,413
2028	320	174	495	6,418	344	2,757
2029	333	181	514	6,931	363	3,120
2030	345	187	533	7,464	382	3,501
2031	358	194	552	8,016	400	3,902
2032	370	200	571	8,587	420	4,321
2033	384	207	591	9,178	440	4,761
2034	395	213	609	9,786	457	5,218
2035	407	220	627	10,414	476	5,694
2036	420	226	646	11,060	495	6,189
2037	430	232	661	11,721	510	6,699
2038	440	237	677	12,398	525	7,225
2039	450	242	692	13,090	541	7,765
2040	460	248	707	13,797	556	8,321

Detailed estimates for primary energy, upstream supply chain, and full-fuel-cycle are presented in Table 3.14. Primary energy savings from commercial energy code activities over the 1992–2012 period equaled 2.75 quads, with annual savings reaching 0.3 quads in 2012. The amount of annual savings from the pre-2012 construction (0.3 quads) are assumed to continue from 2013 until 2040 (projected savings, Stream 1). Cumulative savings from this stream (not in the table) equals 9.4 quads for 2013–2040.

Projected annual primary savings from future code activities (projected savings Stream 2) equal almost 1 quad in 2040. Cumulative savings from this second savings stream equal approximately 14.8 quads for 2013–2040.

When the stream of future primary savings from past construction and the stream of future primary savings from future code activities are combined (Stream 1 + Stream 2), the annual projected savings equal 1.3 quads by 2040. Cumulative projected savings from commercial BECP activities between 2013 and 2040 exceed 24.2 quads by 2040.

Combining 2.75 quads of cumulative historical savings with 24.2 quads of cumulative projected savings brings the total BECP primary energy savings from commercial code activities to almost 27 quads for 1992–2040.

FFC energy savings from commercial energy code activities over the 1992–2012 period equaled 2.8 quads, with annual savings reaching 346 TBtu in 2012. The amount of annual savings from the pre-2012 construction (346 TBtu) are assumed to continue from 2013 until 2040 (projected savings, Stream 1). Cumulative savings from this stream (not shown in the table) equal almost 9.7 quads for 2013–2040.

Projected annual FFC energy savings from future code activities (projected savings Stream 2) equal almost 1 quad in 2040. Cumulative savings from this second savings stream equal 15.3 quads for 2013–2040.

When the stream of future savings from past construction and the stream of future savings from future code activities are combined (Stream 1 + Stream 2), the annual projected savings exceed 1.3 quads by 2040. Cumulative projected savings from commercial BECP activities between 2013 and 2040 equal 25 quads by 2040.

Combining almost 2.8 quads of cumulative historical savings with 25 quads of cumulative projected FFC savings brings the total BECP savings from commercial code activities to 27.8 quads for 1992–2040.

Historical and projected site energy savings were then used to calculate total commercial energy cost savings. For 1992–2012 savings, EIA historical electricity and natural gas prices for the commercial sector[10] were converted to 2012 dollars based on the gross domestic product (GDP) chain-type price index[11] to calculate the annual and cumulative cost savings. Annual cost savings reached $3.3 billion in 2012. Cumulative savings between 1992 and 2012 equaled $29 billion.

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[10] U.S. Energy Information Administration. *Form EIA-826 Database Monthly Electric Utility Sales and Revenue Data* (EIA-826 Sales and Revenue Spreadsheets). Select Table: Sales and Revenue Data by State, Monthly Back to 1990 (Form EIA-826). (Last accessed June 25, 2013.) <www.eia.gov/electricity/data.cfm#sales >. U.S. Energy Information Administration. *Average Price of Natural Gas Sold to Commercial Consumers - by State*. 2012. (Last accessed June 26, 2013.) <www.eia.gov/oil_gas/natural_gas/data_publications/natural_gas_monthly/ngm.html>

[11] Federal Reserve Economic Data, Gross Domestic Product: Chain-type Price Index (GDPCTPI), Index 2005=100, Annual, Seasonally Adjusted. Economic Research Division, Federal Reserve Bank of St. Louis, http://research.stlouisfed.org/fred2

Table 3.14. BECP Commercial Primary and Full-Fuel-Cycle Energy Savings (TBtu)

	Primary	Upstream Supply Chain	FFC, Annual	FFC, Cumulative	Post 2012 construction FFC, Annual	Post 2012 construction FFC, Cumulative
1992	1.2	0.0	1.2	1.2		
1993	2.9	0.1	3.0	4.3		
1994	4.5	0.1	4.7	9		
1995	9	0.3	9	18		
1996	15	0.5	16	34		
1997	23	0.7	24	58		
1998	32	1.0	33	91		
1999	43	1.3	45	135		
2000	56	1.7	57	193		
2001	73	2.2	76	268		
2002	104	3.0	107	375		
2003	127	3.7	131	506		
2004	152	4.4	157	663		
2005	176	5.0	181	843		
2006	203	5.8	209	1,053		
2007	232	6.6	238	1,291		
2008	261	7.5	269	1,560		
2009	283	8.1	291	1,851		
2010	299	8.6	307	2,158		
2011	318	9.0	327	2,485		
2012	336	9.8	346	2,831		
2013	364	10	374	3,205	29	29
2014	387	11	398	3,603	52	80
2015	414	12	425	4,028	80	160
2016	466	13	480	4,508	134	294
2017	511	15	526	5,034	180	474
2018	555	16	571	5,605	225	699
2019	621	18	638	6,243	293	992
2020	681	20	700	6,944	355	1,347
2021	692	21	713	7,657	367	1,714
2022	746	23	768	8,425	423	2,136
2023	795	24	820	9,244	474	2,610
2024	845	25	871	10,115	525	3,135
2025	891	27	917	11,032	571	3,706
2026	859	28	887	11,919	541	4,248
2027	897	29	926	12,845	580	4,828
2028	936	30	966	13,811	620	5,448
2029	972	31	1,003	14,815	658	6,106
2030	1,008	32	1,041	15,856	695	6,801
2031	1,008	34	1,042	16,898	696	7,497
2032	1,044	35	1,079	17,977	733	8,230
2033	1,081	36	1,117	19,094	771	9,001
2034	1,114	37	1,151	20,244	805	9,806
2035	1,147	38	1,185	21,430	840	10,646
2036	1,183	39	1,222	22,651	876	11,522
2037	1,210	40	1,251	23,902	905	12,427
2038	1,238	41	1,279	25,181	934	13,360
2039	1,266	42	1,308	26,490	963	14,323
2040	1,294	43	1,337	27,827	991	15,314

The NIA PLUS model was used to calculate the net present value (NPV) of projected future cost savings. AEO 2013 reference case prices were converted to 2012 dollars and a 7% discount rate was applied. The NPV of annual projected savings in 2040 for Stream 1 equals $0.6 billion. The NPV of cumulative cost savings for Stream 1 exceeds $44 billion. The NPV of annual projected savings in 2040 for Stream 2 equals $2.3 billion. The NPV of cumulative cost savings for Stream 2 equals $61.7 billion. Combined, the NPV of projected future energy cost savings equals approximately $106 billion and the grand total from 1992–2040 is $135 billion. A summary of the cost savings along with the FFC energy savings is presented in Table 3.15.

Table 3.15. Summary of Energy and Cost Savings from the BECP Commercial Energy Code Activities

	Site Energy Savings, TBtu	**Primary Energy Savings, TBtu**	**FFC Energy Savings, TBtu**	**Energy Cost Savings NPV, billion 2012$**
Historical				
Annual in 2012	151	336	346	3.31
Cumulative 1992-2012	1,240	2,751	2,831	29.01
Projected, Stream 1				
Annual in 2040	151	336	346	0.63
Cumulative 2013-2040	4,236	9,408	9,682	44.33
Projected, Stream 2				
Annual in 2040	556	958	991	2.30
Cumulative 2013-2040	8,321	14,818	15,314	61.72
BECP Total				
Annual in 2040	707	1,294	1,337	2.93
Cumulative 1992-2040	13,797	26,977	27,827	135.1

Emissions savings were estimated for carbon dioxide (CO_2), nitrogen oxide (NO_x), mercury (Hg), nitrous oxide (N_2O), methane (CH_4), and sulfur dioxide (SO_2). Detailed annual results for the emissions savings are included in Table 3.16. A summary of historical and projected emissions savings is presented in Table 3.17.

Cumulative emissions reductions between 1992 and 2040 include more than 2.1 billion metric tons (Mt) of CO_2, 2.7 million tons of SO_2, 2.7 million tons of NO_x, and 4.8 tons of Hg.

The value of the FFC CO_2 emission reductions is $1.2 to $4.0 billion based on 2013 domestic social carbon values and a 5% discount rate, or about $17 billion based on 2013 global social cost of carbon (SCC), while NO_x savings contribute almost another $0.7 billion (at $468 per ton in 2012$). Energy cost savings presented in Table 3.15, combined with monetized emission savings presented in Table 3.18, capture consumer benefits to the nation from the commercial BECP activities. Combined consumer benefits from commercial BECP activities are shown in Table 3.19. Depending on the price of CO_2 and NO_x, the NPV of overall consumer benefits can range between $153 and $359 billion (2012$). Out of that total, the energy cost savings constitute $135 billion (2012$).

Table 3.16. Annual Emissions Savings from the BECP Commercial Activities, Full-Fuel-Cycle

	CO_2 *mmt*	NO_x *kt*	Hg *ton*	N_2O *kt*	N_2O *mmt CO_2eq*	CH_4 *kt*	CH_4 *mmt CO_2eq*	SO_2 *kt*
1992	0.1	0.2	0.00	0.0	0.00	0.4	0.0	0.1
1993	0.2	0.5	0.00	0.0	0.00	1.0	0.0	0.3
1994	0.3	0.7	0.00	0.0	0.00	1.5	0.0	0.4
1995	0.7	1.5	0.00	0.0	0.00	2.9	0.1	0.9
1996	1.1	2.5	0.00	0.0	0.00	4.9	0.1	1.5
1997	1.8	3.9	0.00	0.0	0.01	7.5	0.2	2.3
1998	2.4	5.2	0.01	0.0	0.01	10	0.3	3.1
1999	3.2	7.1	0.01	0.0	0.01	14	0.3	4.3
2000	4.2	9.1	0.01	0.0	0.01	18	0.4	5.5
2001	5.5	12	0.01	0.1	0.02	23	0.6	7.3
2002	7.8	17	0.02	0.1	0.03	33	0.8	10
2003	10	21	0.02	0.1	0.03	40	1.0	13
2004	11	25	0.03	0.1	0.04	47	1.2	15
2005	13	29	0.03	0.2	0.05	55	1.4	18
2006	15	33	0.04	0.2	0.05	63	1.6	21
2007	17	38	0.04	0.2	0.06	72	1.8	23
2008	20	43	0.05	0.2	0.07	81	2.0	26
2009	21	47	0.05	0.2	0.07	88	2.2	29
2010	22	49	0.05	0.3	0.08	93	2.3	30
2011	24	52	0.06	0.3	0.08	98	2.4	32
2012	25	56	0.06	0.3	0.08	104	2.6	34
2013	27	60	0.06	0.3	0.09	109	2.7	37
2014	29	63	0.07	0.3	0.09	116	2.9	39
2015	31	67	0.07	0.3	0.09	126	3.1	41
2016	35	76	0.08	0.3	0.10	141	3.5	46
2017	38	83	0.09	0.4	0.11	154	3.9	51
2018	41	90	0.09	0.4	0.12	167	4.2	55
2019	46	101	0.10	0.5	0.14	186	4.7	61
2020	51	110	0.11	0.5	0.15	203	5.1	67
2021	49	45	0.11	0.6	0.16	220	5.5	210
2022	53	48	0.11	0.6	0.18	235	5.9	226
2023	56	52	0.12	0.6	0.19	250	6.2	241
2024	60	55	0.13	0.7	0.20	264	6.6	256
2025	63	57	0.14	0.7	0.22	277	6.9	270
2026	66	66	0.13	0.8	0.23	290	7.2	51
2027	69	69	0.14	0.8	0.23	302	7.6	53
2028	72	72	0.15	0.8	0.24	316	7.9	56
2029	75	75	0.15	0.8	0.25	328	8.2	58
2030	78	78	0.16	0.9	0.26	341	8.5	60
2031	86	85	0.20	0.9	0.27	353	8.8	51
2032	89	88	0.20	0.9	0.28	366	9.2	53
2033	93	92	0.21	1.0	0.29	380	9.5	55
2034	95	94	0.22	1.0	0.30	391	9.8	56
2035	98	97	0.22	1.0	0.31	402	10.0	58
2036	101	100	0.23	1.1	0.32	414	10.4	60
2037	104	102	0.24	1.1	0.32	424	10.6	61
2038	106	105	0.24	1.1	0.33	434	10.9	63
2039	108	107	0.25	1.1	0.34	445	11.1	64
2040	111	109	0.25	1.2	0.34	455	11.4	65
Total	**2,138**	**2,699**	**4.75**	**23**	**6.88**	**8,945**	**224**	**2,742**

Table 3.17. Summary of Emissions Savings from the BECP Commercial Energy Code Activities

	CO_2 *mmt*	NO_x *kt*	Hg *ton*	N_2O *kt*	N_2O *mmt CO_2eq*	CH_4 *kt*	CH_4 *mmt CO_2eq*	SO_2 *kt*
Historical								
Annual in 2012	25	56	0.1	0.3	0.1	104	2.6	34
Cumulative 1992-2012	206	453	0.5	2.4	0.7	857	21	277
Projected, Stream 1								
Annual in 2040	25	56	0.1	0.3	0.1	104	2.6	34
Cumulative 2013-2040	706	1,555	1.6	7.6	2.3	2,911	73	946
Projected, Stream 2								
Annual in 2040	86	54	0.2	0.9	0.3	351	8.8	32
Cumulative 2013-2040	1,226	691	2.6	13.1	3.9	5,176	129	1,519
BECP Total								
Annual in 2040	111	109	0.3	1.2	0.3	455	11	65
Cumulative 1992-2040	2,138	2,699	4.8	23.1	6.9	8,945	224	2,742

Table 3.18. National Cumulative Benefits of the BECP Commercial Activities, 1992−2040

Energy Savings		
Primary	quads	26.98
Upstream	quads	0.85
Full-Fuel-Cycle (total)	quads	27.83
Economic Impacts		
Historical Energy Cost Savings	billion 2012$	29.01
Projected Energy Cost Savings	billion 2012$	106.05
Total Energy Cost Savings	billion 2012$	135.07
Emissions Savings (physical)		
Primary		
CO_2	mmt	2,030
NO_x	kt	1,209
Hg	ton	4.7
N_2O	kt	22.3
N_2O	mmt CO_2eq	6.6
CH_4	kt	156
CH_4	mmt CO_2eq	3.9
SO_2	kt	2,723
Upstream		
CO_2	mmt	108
NO_x	kt	1,489
Hg	ton	0.1
N_2O	kt	0.8
N_2O	mmt CO_2eq	0.2
CH_4	kt	8,788
CH_4	mmt CO_2eq	220
SO_2	kt	19
Full-Fuel-Cycle (total)		
CO_2	mmt	2,138
NO_x	kt	2,699
Hg	ton	4.8
N_2O	kt	23.1
N_2O	mmt CO_2eq	6.9
CH_4	kt	8,945
CH_4	mmt CO_2eq	224
SO_2	kt	2,742

Table 3.18. (contd)

Emissions Savings (monetized)		
Primary		
CO_2 (global)		
5% discount rate, average	billion 2012$	16.5
3% discount rate, average	billion 2012$	67.7
2.5% discount rate, average	billion 2012$	106.9
3% discount rate, 95th %ile	billion 2012$	205.9
CO_2 (domestic)		
5% discount rate, average	billion 2012$	1.2 to 3.8
3% discount rate, average	billion 2012$	4.7 to 15.6
2.5% discount rate, average	billion 2012$	7.5 to 24.6
3% discount rate, 95th %ile	billion 2012$	14.4 to 47.4
NO_x (7% discount rate)		
At 468 2012$/ton	billion 2012$	0.4
At 2,639 2012$/ton	billion 2012$	2.1
At 4,809 2012$/ton	billion 2012$	3.8
Upstream		
CO_2 (global)		
5% discount rate, average	billion 2012$	0.9
3% discount rate, average	billion 2012$	3.6
2.5% discount rate, average	billion 2012$	5.7
3% discount rate, 95th %ile	billion 2012$	11.0
CO_2 (domestic)		
5% discount rate, average	billion 2012$	0.1 to 0.2
3% discount rate, average	billion 2012$	0.3 to 0.8
2.5% discount rate, average	billion 2012$	0.4 to 1.3
3% discount rate, 95th %ile	billion 2012$	0.8 to 2.5
NO_x (7% discount rate)		
At 468 2012$/ton	billion 2012$	0.3
At 2,639 2012$/ton	billion 2012$	1.7
At 4,809 2012$/ton	billion 2012$	3.1
Full-Fuel-Cycle (total)		
CO_2 (global)		
5% discount rate, average	billion 2012$	17.3
3% discount rate, average	billion 2012$	71.3
2.5% discount rate, average	billion 2012$	112.6
3% discount rate, 95th %ile	billion 2012$	216.8
CO_2 (domestic)		
5% discount rate, average	billion 2012$	1.2 to 4
3% discount rate, average	billion 2012$	5 to 16.4
2.5% discount rate, average	billion 2012$	7.9 to 25.9
3% discount rate, 95th %ile	billion 2012$	15.2 to 49.9
NO_x (7% discount rate)		
At 468 2012$/ton	billion 2012$	0.7
At 2,639 2012$/ton	billion 2012$	3.8
At 4,809 2012$/ton	billion 2012$	6.9

Table 3.19. Cumulative Consumer Benefits from BECP Commercial Codes Activities

NPV		
Consumer Energy Cost Savings	*billion 2012$*	135
Consumer & Emissions Value		
Consumers + CO_2 (1st) + NO_x (Low)	*billion 2012$*	153
Consumers + CO_2 (2nd) + NO_x (Med)	*billion 2012$*	210
Consumers + CO_2 (3rd) + NO_x (Med)	*billion 2012$*	251
Consumers + CO_2 (4th) + NO_x (High)	*billion 2012$*	359

Each of the consumer and emissions value estimates above represents a combination of consumer energy cost savings and corresponding scenarios for monetized reduction of CO_2 and NO_x. For example, Consumers + CO_2 (1st) + NO_x (Low) means that savings from the first scenario of CO_2 (5% discount rate, average, global SCC) were combined with savings from the low NO_x cost scenario (at $468 per ton in 2012$) and added to the consumer energy cost savings.

4.0 Residential Assumptions and Estimated Results

This section discusses how the energy savings attributable to different residential energy code versions were compared; how the applicable residential floor space subject to the code was determined; and what adoption and compliance assumptions were used in the analysis.

4.1 Residential Energy Code Performance (Code-to-Code Savings)

Required by the Energy Conservation and Production Act (ECPA, Public Law 94-385), as modified by the Energy Policy Act of 1992 (EPAct 1992), DOE must determine whether the most recent edition of a national model code (e.g., IECC for residential buildings) will save energy when compared to its prior edition. This "determination" process occurs with every new version of the IECC released. Results of the determination analysis are published in the *Federal Register*. If the analysis shows that the revised code is more energy efficient than the earlier code, each state is required to certify that it has reviewed its residential building energy code regarding energy efficiency and made a decision as to whether it is appropriate for that state to update its residential building code at or above the revised code. Results of the Determination provide the foundation for estimating energy savings in this report.

A methodology has been established for evaluating the energy performance of the newest residential energy codes by comparing with its predecessors (Taylor et al. 2012). PNNL evaluates the residential codes as a whole to establish expected energy savings by simulating the effects of the code change(s) on typical, new residential buildings, assuming both code provisions are implemented fully and correctly. Code-to-code energy savings used in the residential benefits estimation are results of this analysis aggregated to the state level.

The most recent analysis[12] evaluated the energy savings and economic impacts of the 2009 and 2012 IECC compared to the 2006 IECC, as well as the 2012 IECC compared to the 2009 IECC. Energy usage was modeled using DOE's EnergyPlus software for two residential building prototypes:

1. Single-Family: A two-story detached home with a 30-ft by 40-ft rectangular shape, 2,400 ft^2 of conditioned floor area, and a 15% window-to-floor ratio, with the window area equally distributed to the four cardinal directions.
2. Multifamily: A three-story building with 18 apartment units (6 units per floor), each with a conditioned floor area of 1,200 ft^2 and a window-to-floor ratio of approximately 10%, with the window area equally distributed on all sides of the building.

The prototypes used in the simulations were intended to represent, respectively, a typical new one- or two-family home or townhouse, and a low-rise multifamily building, such as an apartment, cooperative, or condominium. Four foundation types were examined for each prototype building: vented crawlspace, slab-on-grade, heated basement with wall insulation, and unheated basement with insulation in the floor above the basement. All buildings were evaluated with central air conditioning and each of four heating system types: gas furnace, oil furnace, heat pump, and electric furnace.

[12] Detailed characteristics of the prototypes used in DOE's analyses and detailed weighting factor information are discussed in Taylor et al. (2012).

To facilitate climate-specific energy estimates, PNNL used a set of weather locations that resulted in broad climate coverage at both the climate zone and state level. One weather location per climate zone in each state was selected, including all unique combinations of the zone (temperature-oriented zone designation in the IECC), moisture regime (moist, dry, marine), and warm-humid designation (equivalent to ASHRAE's definition of warm-humid climates). This resulted in a set of 119 weather locations, which was then used to simulate the energy performance of each building energy model.

Energy simulation results for a given location were first weighted across the foundation type, system type, and building type variables, using foundation shares, heating system shares, and new housing starts data, respectively. The weighted, location-specific results were then aggregated to the state level using new construction starts data.

State-level estimates of the energy code performance for the 2006, 2009, and 2012 versions of the IECC were obtained for three fuels (electricity, natural gas, and heating oil) and four groups of end uses (heating, cooling, water heating, and lighting/other). These estimates grouped by fuel type are presented in Table 4.1 in terms of site energy use per household.

The analyzed IECC versions contain provisions that overlap with federal appliance efficiency standards for heating, air conditioning, water heating, and lighting equipment. Because the mandated efficiency will be enforced as a manufacturing standard regardless of whether it is stipulated in the IECC, the inclusion of these requirements in the IECC has no separate energy impact. Therefore, code-to-code savings used in the BECP residential benefits analysis explicitly excluded savings induced by the federal equipment efficiency standards for heating, air conditioning, and water heating. The only exception is lighting. Savings from high-efficacy lighting requirements in the 2009 and 2012 IECC were included because they were an integral part of the building simulations conducted for this analysis. The following lighting efficiency requirements are present in all cases as follows:

1. 2006 IECC: Lighting per Building America benchmark.
2. 2009 IECC: 2006 IECC with 50% high-efficacy lighting.
3. 2012 IECC: 2006 IECC with 75% high-efficacy lighting.

It should be noted that the benchmark (2006 IECC) has a 34% high-efficacy lighting provision. So, the only overlap is the increase from that benchmark level to meet 50% and 75% requirements for the 2009 and 2012 versions of the IECC.

Simulated energy performance estimates presented in Table 4.1 and Table 4.2 were used as a basis for calculating energy performance of the code versions before the 2006 IECC and after the 2012 IECC. For residential code versions predating the 2006 IECC, the energy performance was estimated based on the residential IECC improvement index developed by PNNL. The index is presented in Figure 4.1.

Table 4.1. Residential Annual Energy Use for all IECC Regulated End-Uses, Electricity (site kWh/HH)

	Electr.Heating			Electr.Cooling			Electr.DomHotWater			Electr.Other		
State	IECC 2006	IECC 2009	IECC 2012	IECC 2006	IECC 2009	IECC 2012	IECC 2006	IECC 2009	IECC 2012	IECC 2006	IECC 2009	IECC 2012
Alabama	3,041	2,655	1,454	4,391	3,664	3,148	2,140	2,140	1,925	1,812	1,516	1,296
Alaska	10,416	9,232	5,807	317	319	388	1,874	1,874	1,686	1,948	1,629	1,393
Arizona	902	798	518	8,856	7,410	6,425	532	532	478	1,922	1,608	1,375
Arkansas	4,264	3,693	2,033	3,904	3,388	2,852	1,624	1,624	1,462	1,678	1,404	1,201
California	909	775	338	1,655	1,281	1,344	1,131	1,131	1,017	1,653	1,383	1,182
Colorado	2,806	2,478	1,567	1,673	1,607	1,609	900	900	809	1,826	1,527	1,306
Connecticut	1,817	1,606	1,048	1,902	1,819	1,739	465	465	418	1,788	1,495	1,279
Delaware	8,314	7,079	3,994	2,653	2,545	2,212	3,051	3,051	2,746	1,908	1,595	1,364
District of Columbia	4,068	3,488	2,087	1,957	1,886	1,691	2,407	2,407	2,165	1,127	945	807
Florida	803	719	477	6,927	5,787	5,084	1,930	1,930	1,737	1,815	1,518	1,298
Georgia	3,959	3,428	1,857	4,367	3,659	3,128	2,525	2,525	2,271	1,895	1,584	1,355
Hawaii	48	43	13	8,597	7,682	6,205	2,050	2,050	1,845	1,773	1,483	1,268
Idaho	2,821	2,488	1,588	2,049	1,960	1,898	884	884	795	1,914	1,600	1,369
Illinois	3,054	2,685	1,691	2,396	2,287	2,105	854	854	769	1,622	1,358	1,160
Indiana	3,109	2,721	1,687	2,667	2,542	2,331	870	870	782	1,769	1,479	1,265
Iowa	6,897	6,027	3,650	2,572	2,442	2,246	1,719	1,719	1,547	1,806	1,511	1,292
Kansas	4,803	4,121	2,374	3,270	3,117	2,649	1,554	1,554	1,399	1,797	1,503	1,285
Kentucky	6,771	5,775	3,304	2,598	2,500	2,199	2,572	2,572	2,314	1,788	1,495	1,279
Louisiana	2,672	2,382	1,541	5,510	4,592	4,020	1,510	1,510	1,359	1,935	1,618	1,384
Maine	2,706	2,384	1,465	1,214	1,169	1,184	535	535	482	1,978	1,654	1,415
Maryland	6,427	5,473	3,101	2,689	2,576	2,241	2,844	2,844	2,560	1,748	1,462	1,250
Massachusetts	1,902	1,670	1,060	1,730	1,656	1,615	459	459	412	1,765	1,476	1,262
Michigan	4,509	3,949	2,420	1,691	1,615	1,559	993	993	894	1,882	1,574	1,346
Minnesota	8,359	7,349	4,431	1,656	1,576	1,497	1,841	1,841	1,657	1,734	1,451	1,241
Mississippi	3,291	2,872	1,671	4,824	4,024	3,482	2,145	2,145	1,930	1,881	1,573	1,345
Missouri	4,556	3,925	2,299	3,214	3,068	2,647	1,501	1,501	1,350	1,729	1,447	1,237
Montana	3,337	2,948	1,858	1,250	1,200	1,207	933	933	840	1,724	1,442	1,233
Nebraska	5,396	4,727	2,937	2,784	2,637	2,386	1,613	1,613	1,451	1,716	1,435	1,227
Nevada	1,616	1,399	760	5,847	4,955	3,991	647	648	582	1,891	1,582	1,352
New Hampshire	2,156	1,914	1,240	1,622	1,552	1,503	489	489	440	1,821	1,523	1,303
New Jersey	2,949	2,549	1,522	2,269	2,175	1,966	941	941	847	1,667	1,395	1,193
New Mexico	2,086	1,812	1,052	3,280	2,992	2,638	778	778	700	1,913	1,600	1,368
New York	3,546	3,086	1,847	1,637	1,575	1,515	999	999	898	1,629	1,363	1,165
North Carolina	4,203	3,618	2,014	3,533	3,163	2,725	2,622	2,622	2,359	1,808	1,512	1,293
North Dakota	8,769	7,746	4,739	1,366	1,311	1,270	1,811	1,811	1,629	1,530	1,281	1,094
Ohio	2,839	2,496	1,579	2,050	1,959	1,868	888	888	799	1,798	1,504	1,286
Oklahoma	5,697	4,908	2,560	4,496	3,796	3,116	1,712	1,712	1,540	1,882	1,574	1,346
Oregon	2,800	2,482	1,621	1,353	1,303	1,327	1,389	1,389	1,250	1,830	1,530	1,309
Pennsylvania	3,875	3,402	2,119	2,516	2,394	2,177	1,035	1,035	931	1,933	1,616	1,383
Rhode Island	1,957	1,725	1,112	1,862	1,783	1,726	473	473	426	1,877	1,570	1,342
South Carolina	3,566	3,082	1,607	4,743	4,008	3,346	2,495	2,496	2,245	1,941	1,623	1,388
South Dakota	7,635	6,663	3,942	2,148	2,044	1,898	1,758	1,758	1,582	1,764	1,476	1,262
Tennessee	4,339	3,713	2,114	3,704	3,477	2,991	2,281	2,280	2,053	1,742	1,458	1,246
Texas	2,400	2,125	1,306	5,537	4,644	4,019	1,437	1,437	1,293	1,796	1,502	1,284
Utah	2,351	2,081	1,347	2,815	2,584	2,382	815	815	733	1,818	1,521	1,300
Vermont	2,611	2,286	1,410	1,416	1,354	1,346	510	510	459	1,850	1,547	1,323
Virginia	5,401	4,621	2,632	3,328	3,182	2,731	2,768	2,768	2,491	1,860	1,555	1,330
Washington	3,318	2,916	1,863	1,009	980	1,040	1,432	1,432	1,288	1,780	1,489	1,273
West Virginia	7,683	6,690	4,036	2,177	2,095	1,896	3,045	3,045	2,740	1,788	1,496	1,280
Wisconsin	4,669	4,120	2,545	1,755	1,667	1,571	980	980	882	1,724	1,442	1,233
Wyoming	3,620	3,167	1,891	1,136	1,094	1,114	937	937	843	1,742	1,457	1,247

Table 4.2. Residential Annual Energy Use for all IECC Regulated End-Uses, Natural Gas, and Heating Oil (therm/HH)

	Gas Heating			Gas DomHotWater			Oil Heating			Oil DomHotWater		
State	**IECC 2006**	**IECC 2009**	**IECC 2012**	**IECC 2006**	**IECC 2009**	**IECC 2012**	**IECC 2006**	**IECC 2009**	**IECC 2012**	**IECC 2006**	**IECC 2009**	**IECC 2012**
Alabama	100	89	46	49	49	44	-	-	-	-	-	-
Alaska	949	841	519	162	162	145	3	3	2	1	1	-
Arizona	136	123	73	112	112	101	-	-	-	-	-	-
Arkansas	232	202	107	84	84	75	-	-	-	-	-	-
California	107	92	34	108	108	96	-	-	-	-	-	-
Colorado	518	456	270	168	168	150	1	1	1	-	-	-
Connecticut	422	372	223	118	118	107	230	202	122	64	64	58
Delaware	148	128	71	38	38	34	1	1	-	-	-	-
District of Columbia	73	63	36	31	31	29	-	-	-	-	-	-
Florida	17	16	10	27	27	24	-	-	-	-	-	-
Georgia	78	69	36	33	33	29	-	-	-	-	-	-
Hawaii	-	-	-	-	-	-	-	-	-	-	-	-
Idaho	538	472	279	166	166	149	1	1	1	-	-	-
Illinois	561	494	296	151	151	136	4	3	2	1	1	1
Indiana	573	505	300	153	153	137	4	3	2	1	1	1
Iowa	538	474	281	120	120	108	2	2	1	-	-	-
Kansas	405	350	195	110	110	99	2	1	1	-	-	-
Kentucky	195	170	95	56	56	51	-	-	-	-	-	-
Louisiana	149	134	83	79	79	71	-	-	-	-	-	-
Maine	607	534	308	133	133	119	331	291	168	72	72	65
Maryland	119	102	56	36	36	32	1	1	-	-	-	-
Massachusetts	452	395	227	117	117	105	246	215	124	64	64	57
Michigan	807	712	426	171	170	154	6	5	3	1	1	1
Minnesota	627	552	327	126	126	114	2	2	1	-	-	-
Mississippi	109	96	54	49	49	43	-	-	-	-	-	-
Missouri	386	335	189	108	108	96	2	1	1	-	-	-
Montana	632	557	333	173	173	155	2	2	1	-	-	-
Nebraska	435	383	232	114	114	103	2	2	1	-	-	-
Nevada	269	234	113	129	129	116	1	1	-	-	-	-
New Hampshire	480	424	255	123	123	110	262	231	139	67	67	61
New Jersey	472	410	233	134	134	121	32	27	16	8	8	8
New Mexico	388	335	174	149	149	133	1	1	-	-	-	-
New York	544	476	278	141	141	126	36	32	19	10	10	9
North Carolina	81	71	36	34	34	30	-	-	-	-	-	-
North Dakota	605	534	320	125	125	112	2	2	2	-	-	-
Ohio	537	473	286	156	156	140	3	3	2	1	1	1
Oklahoma	308	267	135	87	87	78	-	-	-	-	-	-
Oregon	322	282	164	127	127	114	1	1	1	-	-	-
Pennsylvania	587	518	309	145	145	130	39	34	21	10	10	9
Rhode Island	456	400	234	120	120	108	249	219	128	65	65	59
South Carolina	69	62	29	33	33	30	-	-	-	-	-	-
South Dakota	565	497	288	122	122	110	2	2	1	-	-	-
Tennessee	133	115	63	51	51	47	-	-	-	-	-	-
Texas	133	119	70	76	76	68	-	-	-	-	-	-
Utah	424	373	218	155	155	139	1	1	1	-	-	-
Vermont	585	515	301	127	127	115	319	281	164	70	70	63
Virginia	99	86	46	36	36	32	1	-	-	-	-	-
Washington	376	329	193	130	130	116	1	1	1	-	-	-
West Virginia	122	108	64	38	38	34	1	1	-	-	-	-
Wisconsin	798	706	419	169	169	151	5	4	3	1	1	1
Wyoming	673	589	333	173	173	155	2	2	1	-	-	-

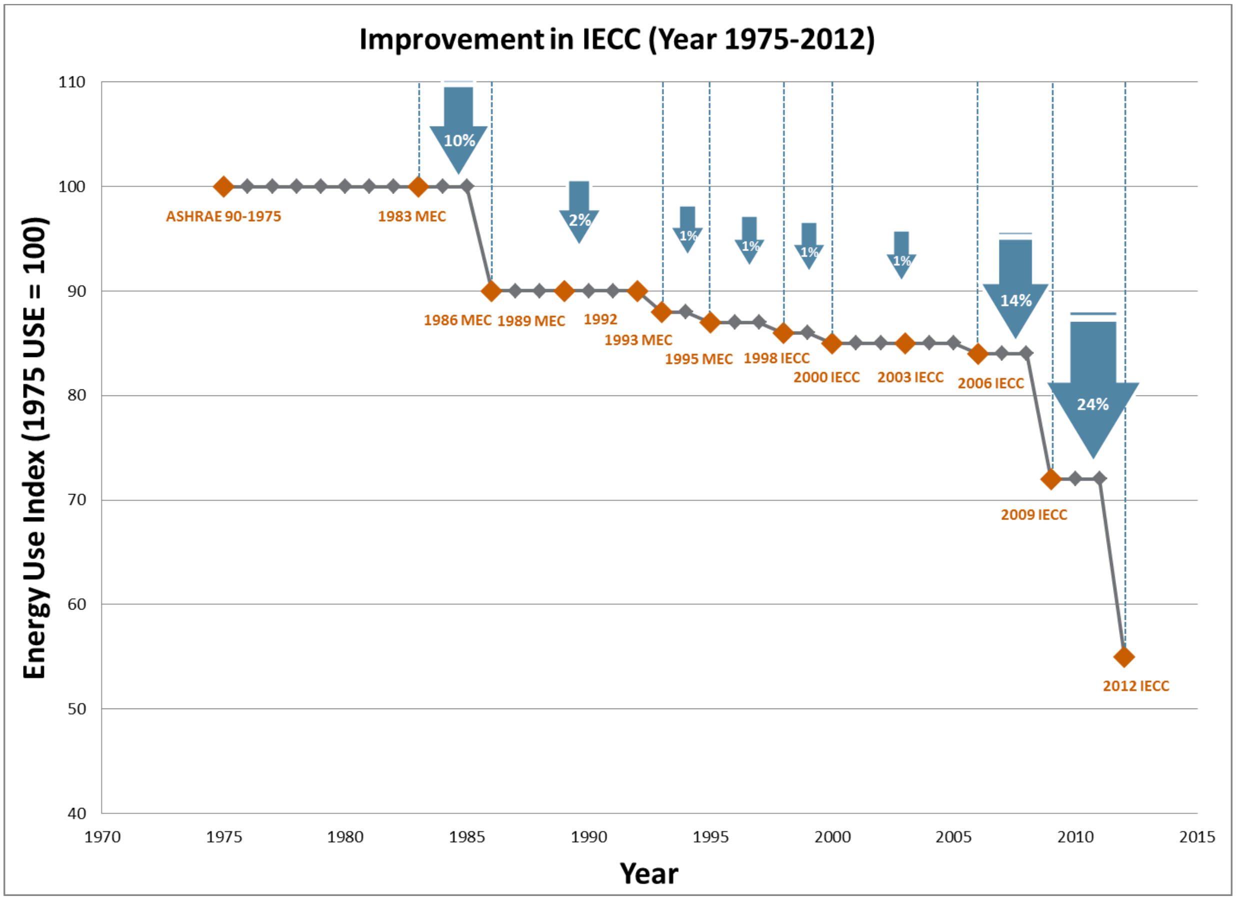

Figure 4.1. IECC Residential Energy Improvement Index

The retroactive code performance scalars for versions between the 1989 MEC and the 2003 IECC were developed from this index using 2006 IECC simulated EUIs as the base. For the code versions prior to the 2006 IECC, BECP is not credited with the energy improvements related to code development. For the 2006, 2009 and 2012 IECC, BECP is credited with 75%, 30%, and 30% of the code-to-code energy efficiency improvement, respectively. These internal estimates are based on the professional judgment of staff involved in code support. This means that if there were a 24% reduction in the EUI between the 2009 IECC and the 2006 IECC in the "with BECP" scenario, we assumed that without the DOE assistance in place the code would have advanced by about 16% instead.

Consistent with BECP shifting from a focus on code development in the past to more support for improvement in code implementation in the future, only 0.5% of the code-to-code energy efficiency improvement was attributed to BECP for the code versions after the 2012 IECC. It was assumed that in the "with BECP" scenario there would be a 5% improvement in the energy use per code cycle, while a 4.5% improvement is expected without the DOE program in place.

Nominal code-to-code energy savings were derived from the code energy performance estimates by comparing the code version that is adopted in the state to the previously active code version. Nominal energy savings were then adjusted by the compliance rates. Residential adoption and compliance assumptions are described in Sections 4.3 and 4.4.

4.2 Residential Floor Space Forecast

Calculating new floor space is integral to the analysis of building energy codes because the potential energy savings are estimated by square foot. However, there are no publicly available data sources that show annual new floor space of residential buildings constructed by state. A further complication is that building codes apply not only to new square footage, but also to additions and major alterations.

The estimates for household stock additions via new construction of single-family and low-rise multifamily buildings, and floor space additions (in terms of household equivalents) to existing single-family homes were combined into one time-series of code-relevant housing additions. Only newly-added space was included; no impacts associated with alterations to existing floor space were incorporated in the estimate.[13] The code-to-code savings were then applied to this housing projection for calculating the national energy benefits of the BECP residential activities. The estimation of the code-applicable floor space is discussed in detail below.

4.2.1 Historical Data for New Residential Construction

Census residential building permit data, for the years 1992 through 2012, were used to develop a time-series of estimated historical completions. Permit data were used, rather than actual census completion data, because permits are available at the state level, whereas completion data are only available at the census region level. The census provides the permit data categorized into the following living unit-based categories:

- 1 unit
- 2 units
- 3 and 4 units
- 5 units or more.

State-level estimates of single-family and low-rise multifamily units are required. For multifamily units, residential building codes only apply to low-rise buildings, i.e., buildings having three or fewer stories above grade, so it is necessary to estimate the fraction of units in the “5 units or more” category that are in low-rise buildings. To accomplish this, several steps were taken:

- Utilized the data from the 2009 Residential Energy Consumption Survey (RECS Table HC2.1). This table categorizes multifamily units, in buildings with five or more units, into various “number of floor” categories.
- Assumed that 60%[14] of the units in the “3-4 Floors” category were in three-floored buildings.
- Added the resulting number of units in three-floored buildings to those in the “1-2 Floors” category, and then divided by the total number of units, which yielded a fraction of units in five-plus unit buildings that are classified as low-rise.
- Applied this fraction to the annual census permit data in order to derive state-level estimates of single-family and low-rise multifamily units.

[13] Based on analysis of the American Housing Survey, alterations accounted for about 0.1% of the existing floor space, with energy-significant alterations comprising only a fraction of that.
[14] Based on the analysis of RECS and CBECS.

Additionally, the fraction of multifamily units classified as low-rise was also estimated by applying the fraction discussed in the previous paragraph to 10 years (2003−2012) of the census permit data. This result was later applied to the AEO-derived multifamily household data to extract an estimate of low-rise multifamily households.

To account for the lag between the permitting and completion of a building, census permit data were converted to estimated completions by introducing a lag of 6 months.[15]

4.2.2 Projected Data for New Construction and Additions to Existing Residential Buildings

The AEO 2012 Reference Case forecasts residential stock (in terms of households) by housing type (single-family, multifamily, and manufactured home) and the nine census divisions. Annual residential stock survival factors from EIA's National Energy Modeling System (NEMS) residential documentation (EIA 2013) were applied to the stock to derive a forecast of additions to residential stock. The survival factors are:

Single-family stock survival factor:	0.996
Multifamily stock survival factor:	0.999
Manufactured home stock survival factor:	0.976

Given that the AEO multifamily data include both low-rise and high-rise multifamily households, it was necessary to apply the fraction of multifamily units classified as low-rise discussed in Section 4.2.1. Adding the resulting low-rise multifamily data to the single-family data provided a forecast of household additions to stock potentially impacted by the residential energy codes.

New construction is not the only means by which building energy codes may provide energy savings. Additions to existing homes are also subject to the energy codes. Estimates of floor space additions due to expansions of existing single-family homes are necessary to capture such impacts. Key steps, assumptions, and details included in this estimation were as follows:

- It was assumed that expansion of existing homes only occurs in the case of single-family, rather than multifamily, homes.
- The single-family stock survival factor was used to calculate surviving stock.
- Based on information included in the NEMS residential documentation, it was assumed that 1% of the surviving, existing single-family stock receives a 600-ft^2 addition in a given year.
- The results were converted to household equivalents, obtained by dividing the added floor space by the size of a prototype single-family home. This prototype, single-family home was assumed to contain 2,400 ft^2 (Taylor et al. 2012, Table 2.1).
- Year-specific ratios of added floor space (in terms of household equivalents) to households added via new construction were calculated. The national-level ratios were later used as scalars to convert state-level new construction numbers to values that include additions to existing single-family homes.

[15] For more detailed data on the typical lag between starts and completions, see census statistics available at http://www.census.gov/construction/nrc/lengthoftime.html.

4.2.3 Integration of Historical and Projected Residential Data

Census-based historical data and the AEO-derived forecast combined into a single time-series served as an estimate of the housing stock impacted by the residential energy codes. The census data are at the state level, and provide data for the years 1992 through 2012. The AEO data are at the census division level, and include data for the years 2005 through 2040. To generate consistent, state-level time-series data through 2040, the following steps were taken:

- Census division-level growth rates embedded in the AEO data were applied to the state-level census data, with the 2012 census data used as the base. This step relied on the implicit assumption that states' shares within each census division remain constant at 2012 levels.
- Expansions of surviving, single-family homes, in terms of household equivalents, were then added to the forecast.
- Previously mentioned national, year-specific scalars were applied to the state-level additions to stock data to integrate additions of space to existing homes.

The resulting estimates represent additions to household stock via new construction of single-family and low-rise multifamily buildings, and additions of floor space (in terms of household equivalents) to existing single-family homes. Only newly added space was included; no impacts associated with alterations to existing floor space were incorporated in the estimate. The code-to-code savings were applied to this housing projection for calculating national energy benefits of the residential BECP activities.

4.3 Adoption of Residential Energy Codes

The same methodology developed for the commercial analysis was used for residential (see Section 3.3). However, the historical explicit, implicit, future adoptions, and counterfactual scenario assumptions for residential energy codes differ from the commercial analysis. Some states adopt residential codes on a different code cycle than commercial or have no code cycle in place for residential but might for commercial. Currently, 43 states have adopted a residential building energy code. The following tables present the residential energy code adoption assumptions and categorizations.

Table 4.4 shows the start of the residential savings stream for both explicit and implicit adoption years. Implicit adoption years are highlighted in orange.

Although the same approach for categorization is used in both the residential and commercial analyses, BECP tracks adoption for commercial and residential energy codes separately. Therefore, the state allocation across the adoption groups is different as presented in Table 4.5. There are six states whose classification varies between residential and commercial: Kentucky, Louisiana, Utah, Vermont, Virginia, and Wisconsin.

Table 4.3. Start Year for Crediting States with Residential Energy Code Savings Based on the Newly Adopted Code

State	MEC 92-95	IECC 1998/2000	IECC 2003	IECC 2006	IECC 2009	IECC 2012
Alabama					2013	
Alaska						
Arizona						
Arkansas	1995		2005			
California	1994	2003		2006	2010	
Colorado	1996		2005	2008		
Connecticut	1999		2005	2009	2012	
Delaware	1996	2004			2010	
District of Columbia	2000	2004			2010	
Florida	1993	2002	2005		2012	
Georgia	1996	2004		2008	2011	
Hawaii	1997			2010		
Idaho		2003	2005	2008	2011	
Illinois					2010	2013
Indiana	1993				2012	
Iowa	1993		2004	2007	2010	
Kansas						
Kentucky	1997	2005		2007	2012	
Louisiana				2011		
Maine			2005		2011	
Maryland	1997	2001	2005	2007	2010	2012
Massachusetts	1998	2001		2008	2010	
Michigan			2009		2011	
Minnesota	2000			2009		
Mississippi						
Missouri						
Montana	1993		2005		2010	
Nebraska			2005		2012	
Nevada			2005	2010	2012	
New Hampshire	1999	2002		2007	2010	
New Jersey	1997		2002	2007	2011	
New Mexico	1994		2004	2008	2012	
New York	1992	2002	2008		2011	
North Carolina	1993	2002	2006	2009	2012	
North Dakota					2011	
Ohio	1995	2002	2005	2009	2013	
Oklahoma					2011	
Oregon	1992	2003	2005	2008	2011	
Pennsylvania			2004	2007	2010	
Rhode Island	1997	2002	2004	2007	2010	
South Carolina	1998	2001	2005	2009	2013	
South Dakota						
Tennessee			2009	2011		
Texas		2001			2012	
Utah	1995	2002	2004	2007		
Vermont	1998	2005			2012	
Virginia	1993	2004	2006	2008	2011	
Washington	1994	2002	2005	2007	2011	2013
West Virginia		2003	2006		2012	
Wisconsin	1999			2009		
Wyoming						

Table 4.4. Start of the Residential Savings Stream Based on Explicit and Implicit Adoption

State	MEC 92-95	IECC 1998/2000	IECC 2003	IECC 2006	IECC 2009	IECC 2012
Alabama	2002	2008	2013	2013	2013	
Alaska	2002	2008	2013	2016		
Arizona	2002	2008	2013	2016		
Arkansas	1995	2005	2005	2016		
California	1994	2003	2006	2006	2010	
Colorado	1996	2005	2005	2008		
Connecticut	1999	2005	2005	2009	2012	
Delaware	1996	2004	2010	2010	2010	
District of Columbia	2000	2004	2010	2010	2010	
Florida	1993	2002	2005	2012	2012	
Georgia	1996	2004	2008	2008	2011	
Hawaii	1997	2008	2010	2010		
Idaho	2002	2003	2005	2008	2011	
Illinois	2002	2008	2010	2010	2010	2013
Indiana	1993	2008	2012	2012	2012	
Iowa	1993	2004	2004	2007	2010	
Kansas	2002	2008	2013	2016		
Kentucky	1997	2005	2007	2007	2012	
Louisiana	2002	2008	2011	2011		
Maine	2002	2005	2005	2011	2011	
Maryland	1997	2001	2005	2007	2010	2012
Massachusetts	1998	2001	2008	2008	2010	
Michigan	2002	2008	2009	2011	2011	
Minnesota	2000	2008	2009	2009		
Mississippi	2002	2008	2013	2016		
Missouri	2002	2008	2013	2016		
Montana	1993	2005	2005	2010	2010	
Nebraska	2002	2005	2005	2012	2012	
Nevada	2002	2005	2005	2010	2012	
New Hampshire	1999	2002	2007	2007	2010	
New Jersey	1997	2002	2002	2007	2011	
New Mexico	1994	2004	2004	2008	2012	
New York	1992	2002	2008	2011	2011	
North Carolina	1993	2002	2006	2009	2012	
North Dakota	2002	2008	2011	2011	2011	
Ohio	1995	2002	2005	2009	2013	
Oklahoma	2002	2008	2011	2011	2011	
Oregon	1992	2003	2005	2008	2011	
Pennsylvania	2002	2004	2004	2007	2010	
Rhode Island	1997	2002	2004	2007	2010	
South Carolina	1998	2001	2005	2009	2013	
South Dakota	2002	2008	2013	2016		
Tennessee	2002	2008	2009	2011		
Texas	2001	2001	2012	2012	2012	
Utah	1995	2002	2004	2007		
Vermont	1998	2005	2012	2012	2012	
Virginia	1993	2004	2006	2008	2011	
Washington	1994	2002	2005	2007	2011	2013
West Virginia	2002	2003	2006	2012	2012	
Wisconsin	1999	2008	2009	2009		
Wyoming	2002	2008	2013	2016		

Table 4.5. State Classifications for Future Residential Energy Code Adoption

Aggressive (code version year +1 year)	**Moderate** (code version year +4 years)	**Slow** (code version year +7 years)
California	Connecticut	Alabama
Florida	Delaware	Alaska
Georgia	District of Columbia	Arizona
Illinois	Idaho	Arkansas
Iowa	Kentucky	Colorado
Maryland	Maine	Hawaii
Massachusetts	Michigan	Indiana
New Hampshire	Montana	Kansas
New York	Nebraska	Louisiana
North Carolina	Nevada	Minnesota
Oregon	New Jersey	Mississippi
Rhode Island	New Mexico	Missouri
Virginia	Ohio	North Dakota
Washington	Pennsylvania	Oklahoma
	South Carolina	South Dakota
	Texas	Tennessee
		Utah
		Vermont
		West Virginia
		Wisconsin
		Wyoming

The full set of residential code adoption assumptions for both scenarios (“with BECP” and “without BECP”) is included in Table 4.6 and Table 4.7. Projected adoption years are highlighted in grey.

Table 4.6. Residential Energy Code Adoption Assumptions for the Scenario "with BECP"

		MEC 92-95	IECC 1998/2000	IECC 2003	IECC 2006	IECC 2009	IECC 2012	IECC 2015	IECC 2018	IECC 2021	IECC 2024
S	Alabama	2002	2008	2013	2013	2013	2019	2022	2025	2028	2031
S	Alaska	2002	2008	2013	2016	2016	2019	2022	2025	2028	2031
S	Arizona	2002	2008	2013	2016	2016	2019	2022	2025	2028	2031
S	Arkansas	1995	2005	2005	2016	2016	2019	2022	2025	2028	2031
A	California	1994	2003	2006	2006	2010	2013	2016	2019	2022	2025
S	Colorado	1996	2005	2005	2008	2016	2019	2022	2025	2028	2031
M	Connecticut	1999	2005	2005	2009	2012	2016	2019	2022	2025	2028
M	Delaware	1996	2004	2010	2010	2010	2016	2019	2022	2025	2028
M	District of Columbia	2000	2004	2010	2010	2010	2016	2019	2022	2025	2028
A	Florida	1993	2002	2005	2012	2012	2013	2016	2019	2022	2025
A	Georgia	1996	2004	2008	2008	2011	2013	2016	2019	2022	2025
S	Hawaii	1997	2008	2010	2010	2016	2019	2022	2025	2028	2031
M	Idaho	2002	2003	2005	2008	2011	2016	2019	2022	2025	2028
A	Illinois	2002	2008	2010	2010	2010	2013	2016	2019	2022	2025
S	Indiana	1993	2008	2012	2012	2012	2019	2022	2025	2028	2031
A	Iowa	1993	2004	2004	2007	2010	2013	2016	2019	2022	2025
S	Kansas	2002	2008	2013	2016	2016	2019	2022	2025	2028	2031
M	Kentucky	1997	2005	2007	2007	2012	2016	2019	2022	2025	2028
S	Louisiana	2002	2008	2011	2011	2016	2019	2022	2025	2028	2031
M	Maine	2002	2005	2005	2011	2011	2016	2019	2022	2025	2028
A	Maryland	1997	2001	2005	2007	2010	2012	2016	2019	2022	2025
A	Massachusetts	1998	2001	2008	2008	2010	2013	2016	2019	2022	2025
M	Michigan	2002	2008	2009	2011	2011	2016	2019	2022	2025	2028
S	Minnesota	2000	2008	2009	2009	2016	2019	2022	2025	2028	2031
S	Mississippi	2002	2008	2013	2016	2016	2019	2022	2025	2028	2031
S	Missouri	2002	2008	2013	2016	2016	2019	2022	2025	2028	2031
M	Montana	1993	2005	2005	2010	2010	2016	2019	2022	2025	2028
M	Nebraska	2002	2005	2005	2012	2012	2016	2019	2022	2025	2028
M	Nevada	2002	2005	2005	2010	2012	2016	2019	2022	2025	2028
A	New Hampshire	1999	2002	2007	2007	2010	2013	2016	2019	2022	2025
M	New Jersey	1997	2002	2002	2007	2011	2016	2019	2022	2025	2028
M	New Mexico	1994	2004	2004	2008	2012	2016	2019	2022	2025	2028
A	New York	1992	2002	2008	2011	2011	2013	2016	2019	2022	2025
A	North Carolina	1993	2002	2006	2009	2012	2013	2016	2019	2022	2025
S	North Dakota	2002	2008	2011	2011	2011	2019	2022	2025	2028	2031
M	Ohio	1995	2002	2005	2009	2013	2016	2019	2022	2025	2028
S	Oklahoma	2002	2008	2011	2011	2011	2019	2022	2025	2028	2031
A	Oregon	1992	2003	2005	2008	2011	2013	2016	2019	2022	2025
M	Pennsylvania	2002	2004	2004	2007	2010	2016	2019	2022	2025	2028
A	Rhode Island	1997	2002	2004	2007	2010	2013	2016	2019	2022	2025
M	South Carolina	1998	2001	2005	2009	2013	2016	2019	2022	2025	2028
S	South Dakota	2002	2008	2013	2016	2016	2019	2022	2025	2028	2031
S	Tennessee	2002	2008	2009	2011	2016	2019	2022	2025	2028	2031
M	Texas	2001	2001	2012	2012	2012	2016	2019	2022	2025	2028
S	Utah	1995	2002	2004	2007	2016	2019	2022	2025	2028	2031
S	Vermont	1998	2005	2012	2012	2012	2019	2022	2025	2028	2031
A	Virginia	1993	2004	2006	2008	2011	2013	2016	2019	2022	2025
A	Washington	1994	2002	2005	2007	2011	2013	2016	2019	2022	2025
S	West Virginia	2002	2003	2006	2012	2012	2019	2022	2025	2028	2031
S	Wisconsin	1999	2008	2009	2009	2016	2019	2022	2025	2028	2031
S	Wyoming	2002	2008	2013	2016	2016	2019	2022	2025	2028	2031

State Classifications: A = Aggressive; M = Moderate; S = Slow

Table 4.7. Residential Energy Code Adoption Assumptions for the Scenario "without BECP"

		MEC 92-95	IECC 1998/2000	IECC 2003	IECC 2006	IECC 2009	IECC 2012	IECC 2015	IECC 2018	IECC 2021	IECC 2024
S	Alabama	2005	2011	2016	2016	2016	2022	2025	2028	2031	2034
S	Alaska	2005	2011	2016	2019	2019	2022	2025	2028	2031	2034
S	Arizona	2005	2011	2016	2019	2019	2022	2025	2028	2031	2034
S	Arkansas	1998	2008	2008	2019	2019	2022	2025	2028	2031	2034
A	California	1995	2004	2007	2007	2011	2014	2017	2020	2023	2026
S	Colorado	1999	2008	2008	2011	2019	2022	2025	2028	2031	2034
M	Connecticut	2005	2011	2011	2015	2018	2022	2025	2028	2031	2034
M	Delaware	2002	2010	2016	2016	2016	2022	2025	2028	2031	2034
M	District of Columbia	2006	2010	2016	2016	2016	2022	2025	2028	2031	2034
A	Florida	1994	2003	2006	2013	2013	2014	2017	2020	2023	2026
A	Georgia	1997	2005	2009	2009	2012	2014	2017	2020	2023	2026
S	Hawaii	2000	2011	2013	2013	2019	2022	2025	2028	2031	2034
M	Idaho	2008	2009	2011	2014	2017	2022	2025	2028	2031	2034
A	Illinois	2003	2009	2011	2011	2011	2014	2017	2020	2023	2026
S	Indiana	1996	2011	2015	2015	2015	2022	2025	2028	2031	2034
A	Iowa	1994	2005	2005	2008	2011	2014	2017	2020	2023	2026
S	Kansas	2005	2011	2016	2019	2019	2022	2025	2028	2031	2034
M	Kentucky	2003	2011	2013	2013	2018	2022	2025	2028	2031	2034
S	Louisiana	2005	2011	2014	2014	2019	2022	2025	2028	2031	2034
M	Maine	2008	2011	2011	2017	2017	2022	2025	2028	2031	2034
A	Maryland	1998	2002	2006	2008	2011	2013	2017	2020	2023	2026
A	Massachusetts	1999	2002	2009	2009	2011	2014	2017	2020	2023	2026
M	Michigan	2008	2014	2015	2017	2017	2022	2025	2028	2031	2034
S	Minnesota	2003	2011	2012	2012	2019	2022	2025	2028	2031	2034
S	Mississippi	2005	2011	2016	2019	2019	2022	2025	2028	2031	2034
S	Missouri	2005	2011	2016	2019	2019	2022	2025	2028	2031	2034
M	Montana	1999	2011	2011	2016	2016	2022	2025	2028	2031	2034
M	Nebraska	2008	2011	2011	2018	2018	2022	2025	2028	2031	2034
M	Nevada	2008	2011	2011	2016	2018	2022	2025	2028	2031	2034
A	New Hampshire	2000	2003	2008	2008	2011	2014	2017	2020	2023	2026
M	New Jersey	2003	2008	2008	2013	2017	2022	2025	2028	2031	2034
M	New Mexico	2000	2010	2010	2014	2018	2022	2025	2028	2031	2034
A	New York	1993	2003	2009	2012	2012	2014	2017	2020	2023	2026
A	North Carolina	1994	2003	2007	2010	2013	2014	2017	2020	2023	2026
S	North Dakota	2005	2011	2014	2014	2014	2022	2025	2028	2031	2034
M	Ohio	2001	2008	2011	2015	2019	2022	2025	2028	2031	2034
S	Oklahoma	2005	2011	2014	2014	2014	2022	2025	2028	2031	2034
A	Oregon	1993	2004	2006	2009	2012	2014	2017	2020	2023	2026
M	Pennsylvania	2008	2010	2010	2013	2016	2022	2025	2028	2031	2034
A	Rhode Island	1998	2003	2005	2008	2011	2014	2017	2020	2023	2026
M	South Carolina	2004	2007	2011	2015	2019	2022	2025	2028	2031	2034
S	South Dakota	2005	2011	2016	2019	2019	2022	2025	2028	2031	2034
S	Tennessee	2005	2011	2012	2014	2019	2022	2025	2028	2031	2034
M	Texas	2007	2007	2018	2018	2018	2022	2025	2028	2031	2034
S	Utah	1998	2005	2007	2010	2019	2022	2025	2028	2031	2034
S	Vermont	2001	2008	2015	2015	2015	2022	2025	2028	2031	2034
A	Virginia	1994	2005	2007	2009	2012	2014	2017	2020	2023	2026
A	Washington	1995	2003	2006	2008	2012	2014	2017	2020	2023	2026
S	West Virginia	2005	2006	2009	2015	2015	2022	2025	2028	2031	2034
S	Wisconsin	2002	2011	2012	2012	2019	2022	2025	2028	2031	2034
S	Wyoming	2005	2011	2016	2019	2019	2022	2025	2028	2031	2034

State Classifications: A = Aggressive; M = Moderate; S = Slow

4.4 Residential Energy Code Compliance

The logic applied in developing residential energy code compliance assumptions was similar to that used for the commercial compliance assumptions. It is the relative difference in compliance rates between the two scenarios, rather than the absolute level of compliance, that drives the estimation. Very little comparable information exists on state-by-state compliance rates. Therefore, uniform, national compliance rates parameterized based on the review of the available compliance studies were applied for the "with BECP" scenario. These compliance rates are presented in Table 4.8.

Table 4.8. Residential Code Compliance Assumptions for "With BECP" Scenario

	(a) Initially Compliant Buildings	(b) Initially Non-compliant Buildings	(c) **Weighted Compliance, Initial (Energy Terms)**	(d) Compliant Buildings after 10 Years	(e) Non-compliant Buildings after 10 Years	(f) **Weighted Compliance, after 10 Years (Energy Terms)**
MEC 92 – 200 IECC						
Compliance in legal terms	60%	40%		80%	20%	
Compliance in energy terms	1.00	0.40	**76%**	1.00	0.40	**88%**
2003 IECC						
Compliance in legal terms	65%	35%		80%	20%	
Compliance in energy terms	1.00	0.50	**83%**	1.00	0.50	**90%**
2006 IECC						
Compliance in legal terms	70%	30%		90%	10%	
Compliance in energy terms	1.00	0.50	**85%**	1.00	0.50	**95%**
2009 IECC and after						
Compliance in legal terms	50%	50%		80%	20%	
Compliance in energy terms	1.00	0.40	**70%**	1.00	0.40	**88%**

(a) Compliance in legal terms: percent of new housing units fully meeting provisions of code change.
(b) Compliance in energy terms: achieved fraction of nominal code-to-code energy savings in buildings that only partially meet the new code requirements (i.e., buildings that are noncompliant in legal terms).
Columns (c) and (f): Weighted average fraction of potential savings for both legally compliant and not legally compliant buildings.

Compliance rates presented in the table above apply to all modeled end-use groups uniformly. Similar logic discussed in Section 3.4 is applied here. Compliance assumptions for the scenario "without BECP" were developed based on the state categorization. The percentage point difference in compliance between scenarios "with BECP" and "without BECP" is presented in Table 4.9.

Table 4.9. Percent Point Difference between Residential Compliance Levels "with BECP" and "without BECP" Scenarios

	Before 2006 IECC	**2006 IECC and after**
Aggressive	5%	10%
Moderate	20%	30%
Slow	10%	20%

4.5 Estimated Benefits of the Residential BECP Activities

This analysis assumed that BECP residential energy code efforts improve code-to-code energy efficiency by supporting code development, accelerating the adoption of the most recent residential building energy codes (or equivalent), and increasing compliance with the code provisions. Note that energy savings achieved in California, Washington, Oregon, and Florida were totally or partially removed from the BECP benefits calculation as presented in Table 4.10. [16]

Table 4.10. States Excluded from the BECP Residential Benefits Calculation

State	Residential
California	All years excluded
Florida	Excluded 1992–2011
Oregon	All years excluded
Washington	Excluded 1992–2012

Following the analysis methodology used by DOE's Appliance and Equipment Standards Program, site energy savings were first converted to source terms, which includes energy used in generation, transmission, and distribution (primary energy). Energy used further "upstream" in the mining, processing, and transportation of fuels was calculated using the NIA PLUS model (Coughlin 2012)[17] and added to the primary energy savings to yield full-fuel-cycle (FFC) energy savings. Emissions savings and emissions monetization were also calculated using the NIA PLUS model. Detailed explanations of technical assumptions, scalars, and cost rates underlying this set of calculations are available (10 CFR 429 and 430).

The remainder of this section discusses estimated site and primary energy savings, FFC savings, emissions savings, emissions monetization, and consumer benefits.

BECP historical and projected energy savings (site or delivered energy) are presented in Table 4.11. For the historical portion of the Program savings, cumulative site energy savings between 1992 and 2012 totaled 719 TBtu, with the annual site energy savings being approximately 81 TBtu at the end of 2012.

The amount of annual savings (81 TBtu) in 2012 from the pre-2012 construction is assumed to continue from 2013 until 2040 because of the implicit assumption that the average expected lifetime of a residential building exceeds the forecast horizon. This portion comprises the first stream of savings. Cumulative savings from this stream equal 2.3 quads in 2040.

Projected annual site savings from future code activities and construction equal 458 TBtu in 2040 and cumulative savings from this second savings stream equal 7.2 quads from 2013 through 2040.

When the stream of future savings from past construction and the stream of future savings for future construction are combined, the annual projected savings equal 539 TBtu by 2040. Cumulative savings from residential BECP activities reach 10.2 quads by 2040.

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[16] CA and OR have been excluded from this analysis due to their history of developing their own advanced state-specific residential code without direct assistance from BECP's tools or resources. WA and FL have been partially excluded due to their history of adopting their own state-specific codes without direct assistance from BECP's tools or resources; however, WA and FL received technical assistance within the past 3 years to implement their state-specific codes into RES*check*. WA: implemented its residential code into RES*check* in 2013. FL: implemented its residential state code into RES*check* in 2011.
[17] Coughlin, K., Calculation of Full Fuel Cycle Multipliers for Energy Use in Buildings. *LBNL Paper*, 2012.

Table 4.11. BECP Residential Site Energy Savings (TBtu)

	Electricity TBtu	Natural Gas TBtu	Heating Oil TBtu	Total, Annual TBtu	Total, Cumulative TBtu	Annual	Cumulative
1992	0.10	0.26	0.02	0.4	0.4		
1993	0.68	0.76	0.03	1.5	1.9		
1994	0.88	1.18	0.03	2.1	3.9		
1995	1.31	2.07	0.04	3.4	7.4		
1996	2.09	3.13	0.05	5.3	13		
1997	2.90	4.41	0.08	7.4	20		
1998	3.72	5.72	0.16	10	30		
1999	4.61	7.18	0.25	12	42		
2000	5.62	8.82	0.32	15	56		
2001	7.47	10.71	0.42	19	75		
2002	11	15	0.58	27	102		
2003	14	19	0.69	34	136		
2004	19	23	0.84	43	179		
2005	22	28	1.03	51	229		
2006	25	32	1.20	58	288		
2007	27	35	1.35	63	351		
2008	29	37	1.45	68	419		
2009	31	39	1.51	71	490		
2010	32	40	1.59	73	563		
2011	33	41	1.65	75	638	**Annual**	**Cumulative**
2012	36	43	1.73	81	719	**Post 2012 construction only**	
2013	41	48	1.94	91	811	10	10
2014	46	52	2.10	99	910	18	29
2015	51	56	2.28	109	1,019	28	56
2016	61	67	2.72	131	1,150	50	106
2017	71	77	3.05	151	1,300	70	176
2018	79	86	3.38	169	1,469	87	263
2019	91	102	3.82	197	1,666	116	379
2020	103	118	4.22	224	1,891	143	523
2021	114	133	4.61	251	2,142	170	693
2022	124	146	4.94	274	2,416	193	886
2023	133	158	5.25	297	2,713	216	1,102
2024	143	171	5.55	319	3,032	238	1,340
2025	151	180	5.79	337	3,369	256	1,596
2026	159	188	6.01	353	3,723	272	1,868
2027	167	197	6.22	370	4,092	289	2,157
2028	174	205	6.41	385	4,477	304	2,461
2029	181	213	6.61	401	4,878	320	2,780
2030	188	221	6.80	416	5,294	335	3,115
2031	195	228	6.97	430	5,724	349	3,464
2032	201	235	7.13	444	6,168	363	3,827
2033	208	243	7.29	457	6,625	376	4,203
2034	213	249	7.43	469	7,094	388	4,591
2035	219	255	7.57	481	7,575	400	4,991
2036	224	261	7.71	493	8,068	412	5,403
2037	230	267	7.84	504	8,572	423	5,826
2038	235	273	7.97	516	9,088	435	6,261
2039	240	279	8.09	528	9,616	447	6,708
2040	246	285	8.21	539	10,155	458	7,166

Detailed estimates for primary energy, upstream supply chain, and FFC energy savings are presented in Table 4.12. Energy and cost savings from the BECP residential activities are summarized in Table 4.13. Accumulated primary energy savings from residential energy code activities over the period of 1992–2012 equal 1.3 quads, with annual savings reaching 0.15 quads in 2012 (Table 4.13). The amount of annual savings (0.15 quads in 2012) from the pre-2012 construction was assumed to continue from 2013 until 2040 (projected savings, Stream 1). Cumulative savings from this stream equal 4.2 quads for 2013–2040 (Table 4.13).

Projected annual primary savings from future code activities (projected savings, Stream 2) equal 0.7 quad in 2040. Cumulative savings from this second savings stream equal approximately 11.7 quads for 2013–2040. When the stream of future primary savings from past construction and the stream of future primary savings from future code activities are combined (Stream 1 + Stream 2), the annual projected primary savings equal 0.9quad by 2040. Cumulative projected primary savings from residential BECP activities between 2013 and 2040 equal 15.9 quads by 2040.

Combining 1.3 quads of cumulative historical savings (1992–2012) with 15.9 quads of cumulative projected savings (2013–2040) brings the total BECP primary energy savings from residential code activities to 17.2 quads for 1992–2040 (not shown in the table).

FFC energy savings from residential energy code activities over the 1992–2012 periods equal 1.35 quads, with annual savings reaching 155 TBtu in 2012. The amount of annual savings from the pre-2012 construction (155 TBtu) continue from 2013 until 2040 (projected savings, Stream 1). Cumulative savings from this stream (not shown in the table) equal 4.3 quads for 2013–2040.

Projected annual FFC savings from future code activities (projected savings, Stream 2) equal 0.8 quad in 2040. Cumulative FFC savings from this second savings stream equal 12.2 quads for 2013–2040.

When the stream of future savings from past construction and the stream of future savings from future code activities are combined (Stream 1 + Stream 2), the annual projected future savings equal 0.9 quads by 2040. Cumulative projected FFC savings from residential BECP activities between 2013 and 2040 reach 16.5 quads by 2040.

Combining 1.3 quads of cumulative historical savings with 16.5 quads of cumulative projected savings, brings the total BECP FFC savings from residential code activities to 17.9 quads for 1992–2040.

Historical and projected site energy savings were then used to calculate energy cost savings. For 1992–2012 savings, EIA historical electricity and natural gas prices for the residential sector were converted to 2012 dollars based on the GDP chain-type price index[18] to calculate the annual and cumulative cost savings.

As shown in Table 4.13, annual historical cost savings reach $1.7 billion in 2012 and cumulative savings between 1992 and 2012 equal $15.6 billion.

[18] Federal Reserve Economic Data, Gross Domestic Product: Chain-type Price Index (GDPCTPI), Index 2005=100, Annual, Seasonally Adjusted. Economic Research Division, Federal Reserve Bank of St. Louis, http://research.stlouisfed.org/fred2

Table 4.12. BECP Residential Primary and Full-Fuel-Cycle Energy Savings (TBtu)

	Primary	Upstream Supply Chain	FFC, Annual	FFC, Cumulative	Post 2012 construction FFC, Annual	Post 2012 construction FFC, Cumulative
1992	0.6	0.0	0.6	0.6		
1993	2.7	0.1	2.8	3.5		
1994	3.7	0.2	3.9	7		
1995	6	0.3	6	13		
1996	9	0.4	10	23		
1997	13	0.6	13	36		
1998	17	0.8	17	54		
1999	21	1.0	22	75		
2000	25	1.2	26	102		
2001	32	1.5	34	136		
2002	47	2.2	50	185		
2003	61	2.7	63	249		
2004	77	3.4	81	330		
2005	92	4.0	96	425		
2006	106	4.6	110	536		
2007	114	5.0	119	655		
2008	122	5.4	127	782		
2009	127	5.6	133	915		
2010	132	5.8	138	1,053		
2011	136	5.9	142	1,195		
2012	149	6.4	155	1,350		
2013	168	7	175	1,525	20	20
2014	184	8	192	1,717	37	57
2015	203	8	211	1,928	56	113
2016	245	10	255	2,183	100	212
2017	282	11	293	2,476	138	351
2018	315	13	328	2,803	173	523
2019	367	15	381	3,185	227	750
2020	415	17	432	3,617	277	1,027
2021	434	19	453	4,069	298	1,324
2022	473	21	494	4,563	339	1,663
2023	511	22	533	5,096	378	2,041
2024	549	24	573	5,669	418	2,459
2025	580	25	605	6,274	450	2,909
2026	584	26	610	6,884	455	3,364
2027	611	27	638	7,522	483	3,848
2028	637	28	666	8,188	511	4,358
2029	663	29	692	8,880	538	4,896
2030	689	30	720	9,600	565	5,460
2031	702	32	734	10,334	579	6,039
2032	725	33	757	11,091	602	6,642
2033	748	34	781	11,872	626	7,268
2034	767	34	801	12,674	646	7,914
2035	786	35	822	13,495	667	8,581
2036	806	36	842	14,337	687	9,268
2037	825	37	862	15,199	707	9,975
2038	844	38	882	16,081	727	10,702
2039	864	38	902	16,983	747	11,449
2040	883	39	922	17,905	767	12,216

Table 4.13. Summary of Energy and Cost Savings from the BECP Residential Energy Code Activities

	Site Energy Savings, TBtu	Primary Energy Savings, TBtu	FFC Energy Savings, TBtu	Energy Cost Savings NPV, billion 2012$
Historical				
Annual in 2012	81	149	155	1.7
Cumulative 1992–2012	719	1,293	1,350	15.6
Projected, Stream 1				
Annual in 2040	81	149	155	0.3
Cumulative 2013–2040	2,270	4,160	4,339	23.8
Projected, Stream 2				
Annual in 2040	458	734	767	2.0
Cumulative 2013–2040	7,166	11,700	12,216	55.8
BECP Total				
Annual in 2040	539	883	922	2.3
Cumulative 1992–2040	10,155	17,153	17,905	95.2

For projected savings, the NIA PLUS model was used to calculate the NPV of the future cost savings. AEO 2013 reference case prices were converted to 2012 dollars and a 7% discount rate was applied. The NPV of annual projected savings in 2040 for Stream 1 equals $0.3 billion. The NPV of cumulative cost saving for Stream 1 equals $23.8 billion. The NPV of annual projected savings in 2040 for Stream 2 equals almost $2 billion. The NPV of cumulative cost savings for Stream 2 equals $55.8 billion. Combined, the NPV of projected energy cost savings equals almost $80 billion. Total accumulated cost savings to consumers from the BECP residential energy code activities for 1992–2040 equal $95.2 billion.

Emissions savings were estimated for CO_2, NO_x, Hg, N_2O, CH_4, and SO_2. Detailed annual results for the emissions savings are included in Table 4.14. A summary of historical and projected emissions savings is presented in Table 4.15.

The cumulative emissions reduction between 1992 and 2040 includes 1.3 billion metric tons (Mt) of CO_2, 1.8 million tons of NO_x, 2.8 tons of Hg, and 1.1 million tons of SO_2.

The value of the CO_2 emissions reduction is $0.7 to 2.4 billion (2012$) based on 2013 domestic social carbon values and a 5% discount rate, or about 10.6 billion based on global SCC, while NO_x savings contribute at least another $0.4 billion (at $468 per ton in 2012$). Energy cost savings presented in Table 4.13, combined with monetized emissions savings presented in Table 4.16, capture consumer benefits to the nation from the residential BECP activities. Combined consumer benefits from residential BECP activities are shown in Table 4.17. Depending on the price of CO_2 and NO_x, the NPV of overall consumer benefits can range between $106 and 235 billion (2012$). Out of that total, the energy cost savings constitute $95 billion (2012$).

Table 4.14. Annual Emissions Savings from the BECP Residential Activities, Full-Fuel-Cycle

	CO_2 *mmt*	NO_x *kt*	Hg *ton*	N_2O *kt*	N_2O *mmt CO_2eq*	CH_4 *kt*	CH_4 *mmt CO_2eq*	SO_2 *kt*
1992	0.0	0.1	0.00	0.00	0.00	0.26	0.0	0.0
1993	0.2	0.4	0.00	0.00	0.00	1.00	0.0	0.2
1994	0.3	0.6	0.00	0.00	0.00	1.43	0.0	0.3
1995	0.4	0.9	0.00	0.00	0.00	2.36	0.1	0.5
1996	0.7	1.5	0.00	0.01	0.00	3.64	0.1	0.7
1997	0.9	2.1	0.00	0.01	0.00	5.08	0.1	1.0
1998	1.2	2.7	0.00	0.01	0.00	7	0.2	1.3
1999	1.5	3.3	0.00	0.01	0.00	8	0.2	1.6
2000	1.8	4.1	0.00	0.02	0.01	10	0.3	2.0
2001	2.3	5.3	0.00	0.02	0.01	13	0.3	2.6
2002	3.4	7.7	0.01	0.03	0.01	18	0.5	3.9
2003	4.4	9.9	0.01	0.04	0.01	23	0.6	5.1
2004	5.6	12.7	0.01	0.06	0.02	29	0.7	6.6
2005	6.6	15.0	0.01	0.07	0.02	35	0.9	7.8
2006	7.6	17.3	0.01	0.08	0.02	40	1.0	9.0
2007	8.2	18.6	0.01	0.08	0.02	43	1.1	9.6
2008	8.8	19.9	0.02	0.09	0.03	46	1.2	10.3
2009	9.2	20.8	0.02	0.09	0.03	48	1.2	10.8
2010	9.5	21.6	0.02	0.10	0.03	50	1.3	11.2
2011	9.8	22.3	0.02	0.10	0.03	51	1.3	11.5
2012	10.8	24.5	0.02	0.10	0.03	55	1.4	12.7
2013	12.2	27.5	0.02	0.12	0.03	60	1.5	14.5
2014	13.3	29.8	0.02	0.12	0.04	65	1.6	15.8
2015	14.7	32.9	0.02	0.13	0.04	72	1.8	17.2
2016	17.8	39.8	0.03	0.16	0.05	86	2.2	20.9
2017	20.4	45.7	0.03	0.18	0.05	99	2.5	24.0
2018	22.8	50.9	0.04	0.21	0.06	110	2.7	26.8
2019	26.6	59.2	0.05	0.24	0.07	128	3.2	31.0
2020	30.0	66.9	0.05	0.27	0.08	145	3.6	34.9
2021	30.4	34.9	0.06	0.30	0.09	162	4.0	41.8
2022	33.2	37.8	0.06	0.33	0.10	176	4.4	45.5
2023	35.8	40.8	0.07	0.36	0.11	189	4.7	49.0
2024	38.4	43.6	0.07	0.38	0.11	203	5.1	52.5
2025	40.6	45.8	0.08	0.41	0.12	213	5.3	55.6
2026	44.4	52.6	0.08	0.43	0.13	224	5.6	25.3
2027	46.5	54.9	0.08	0.45	0.13	234	5.8	26.5
2028	48.5	57.1	0.09	0.46	0.14	244	6.1	27.7
2029	50.5	59.3	0.09	0.48	0.14	253	6.3	28.8
2030	52.5	61.6	0.09	0.50	0.15	264	6.6	30.0
2031	58.9	68.4	0.14	0.52	0.15	273	6.8	40.2
2032	60.8	70.7	0.15	0.53	0.16	282	7.0	41.6
2033	62.8	73.0	0.15	0.55	0.16	291	7.3	42.9
2034	64.4	74.7	0.16	0.56	0.17	298	7.4	44.0
2035	66.0	76.4	0.16	0.58	0.17	305	7.6	45.1
2036	67.6	77.5	0.16	0.59	0.18	312	7.8	46.3
2037	69.3	79.3	0.17	0.60	0.18	319	8.0	47.4
2038	70.9	81.1	0.17	0.62	0.18	327	8.2	48.5
2039	72.5	82.8	0.18	0.63	0.19	334	8.4	49.7
2040	74.1	84.6	0.18	0.64	0.19	342	8.5	50.8
Total	**1,339**	**1,821**	**2.8**	**12.3**	**3.66**	**6,497**	**162**	**1,133**

Table 4.15. Summary of Emissions Savings from the BECP Residential Energy Code Activities

	CO_2 mmt	NO_x kt	Hg ton	N_2O kt	N_2O mmt CO_2eq	CH_4 kt	CH_4 mmt CO_2eq	SO_2 kt
Historical								
Annual in 2012	11	24	0.0	0.1	0.0	55	1.4	13
Cumulative 1992-2012	93	211	0.2	0.9	0.3	490	12	109
Projected, Stream 1								
Annual in 2040	11	24	0.0	0.1	0.0	55	1.4	13
Cumulative 2013-2040	301	685	0.5	2.9	0.9	1,529	38	355
Projected, Stream 2								
Annual in 2040	63	60	0.2	0.5	0.2	287	7.2	38
Cumulative 2013-2040	945	925	2.1	8.5	2.5	4,479	112	669
BECP Total								
Annual in 2040	74	85	0.2	0.6	0.2	342	9	51
Cumulative 1992-2040	1,339	1,821	2.8	12.3	3.7	6,497	162	1,133

Table 4.16. National Cumulative Benefits of the BECP Residential Activities, 1992–2040

Energy Savings		
Primary	quads	17.2
Upstream	quads	0.8
Full-Fuel-Cycle (total)	quads	17.9
Economic Impacts		
Historical Energy Cost Savings	billion 2012$	15
Projected Energy Cost Savings	billion 2012$	80
Total Energy Cost Savings	billion 2012$	95
Emissions Savings (physical)		
Primary		
CO_2	mmt	1,263
NO_x	kt	744
Hg	ton	2.8
N_2O	kt	11.8
N_2O	mmt CO_2eq	3.5
CH_4	kt	84
CH_4	mmt CO_2eq	2.1
SO_2	kt	1,123
Upstream		
CO_2	mmt	76
NO_x	kt	1,077
Hg	ton	0.0
N_2O	kt	0.5
N_2O	mmt CO_2eq	0.1
CH_4	kt	6,413
CH_4	mmt CO_2eq	160
SO_2	kt	10
Full-Fuel-Cycle (total)		
CO_2	mmt	1,339
NO_x	kt	1,821
Hg	ton	2.8
N_2O	kt	12.3
N_2O	mmt CO_2eq	3.7
CH_4	kt	6,497
CH_4	mmt CO_2eq	162
SO_2	kt	1,133

Table 4.16. (contd)

Emissions Savings (monetized)		
Primary		
CO_2 (global)		
5% discount rate, average	billion 2012$	10.0
3% discount rate, average	billion 2012$	41.9
2.5% discount rate, average	billion 2012$	66.2
3% discount rate, 95th %ile	billion 2012$	128.0
CO_2 (domestic)		
5% discount rate, average	billion 2012$	0.7 to 2.3
3% discount rate, average	billion 2012$	2.9 to 9.6
2.5% discount rate, average	billion 2012$	4.6 to 15.2
3% discount rate, 95th %ile	billion 2012$	9 to 29.4
NO_x (7% discount rate)		
At 468 2012$/ton	billion 2012$	0.2
At 2,639 2012$/ton	billion 2012$	1.1
At 4,809 2012$/ton	billion 2012$	2.0
Upstream		
CO_2 (global)		
5% discount rate, average	billion 2012$	0.6
3% discount rate, average	billion 2012$	2.5
2.5% discount rate, average	billion 2012$	4.0
3% discount rate, 95th %ile	billion 2012$	7.7
CO_2 (domestic)		
5% discount rate, average	billion 2012$	0 to 0.1
3% discount rate, average	billion 2012$	0.2 to 0.6
2.5% discount rate, average	billion 2012$	0.3 to 0.9
3% discount rate, 95th %ile	billion 2012$	0.5 to 1.8
NO_x (7% discount rate)		
At 468 2012$/ton	billion 2012$	0.2
At 2,639 2012$/ton	billion 2012$	1.2
At 4,809 2012$/ton	billion 2012$	2.1
Full-Fuel-Cycle (total)		
CO_2 (global)		
5% discount rate, average	billion 2012$	10.6
3% discount rate, average	billion 2012$	44.4
2.5% discount rate, average	billion 2012$	70.2
3% discount rate, 95th %ile	billion 2012$	135.7
CO_2 (domestic)		
5% discount rate, average	billion 2012$	0.7 to 2.4
3% discount rate, average	billion 2012$	3.1 to 10.2
2.5% discount rate, average	billion 2012$	4.9 to 16.1
3% discount rate, 95th %ile	billion 2012$	9.5 to 31.2
NO_x (7% discount rate)		
At 468 2012$/ton	billion 2012$	0.4
At 2,639 2012$/ton	billion 2012$	2.3
At 4,809 2012$/ton	billion 2012$	4.1

Table 4.17. Cumulative Consumer Benefits from BECP Residential Energy Code Activities

NPV		
Consumer Energy Cost Savings	billion 2012$	95
Consumer and Emissions Value		
Consumers + CO_2 (1st) + NO_x (Low)	billion 2012$	106
Consumers + CO_2 (2nd) + NO_x (Med)	billion 2012$	142
Consumers + CO_2 (3rd) + NO_x (Med)	billion 2012$	168
Consumers + CO_2 (4th) + NO_x (High)	billion 2012$	235

Each of the consumer and emissions value estimates above represents a combination of consumer energy cost savings and corresponding scenarios for monetized reduction of CO_2 and NO_x. For example, Consumers + CO_2 (1st) + NO_x (Low) means that savings from the first scenario of CO_2 (5% discount rate, average, global SCC) were combined with savings from the low NO_x cost scenario (at $468 per ton in 2012$) and added to the consumer energy cost savings.

5.0 National Energy, Economic, and Environmental Benefits

This analysis defines DOE BECP impact as improving energy efficiency of the national building model codes and standards, accelerating the adoption of the most recent code (or equivalent), and increasing compliance with the code provisions.

BECP historical and projected energy savings are presented in Table 5.1. For the historical portion of the Program savings, cumulative primary energy savings between 1992 and 2012 total 4quads, with the annual energy savings being approximately 0.5 quads in 2012. For the projected program savings, accumulated primary energy savings from 2013 through 2040 reach 40.1 quads, with the annual savings of 2.2 quads in 2040. The cumulative energy savings attributed from the Program total nearly 46 quads of FFC energy, or 44 quads of primary energy. The Program may save consumers up to $230 billion on their utility bills by 2040. Table 5.2 provides the breakdown of energy and cost savings between commercial and residential activities.

Table 5.1. Summary of Energy and Cost Savings from BECP Energy Code Activities

	Site Energy Savings,[a] quads	**Primary Energy Savings,[b] quads**	**FFC Energy Savings,[c] quads**	**Energy Cost Savings NPV, billion 2012$**
Historical				
Annual in 2012	0.2	0.5	0.5	5.0
Cumulative 1992−2012	2.0	4.0	4.2	44.6
Projected, 2013−2040 Construction				
Annual in 2040	1.2	2.2	2.3	5.2
Cumulative 2013−2040	22.0	40.1	41.6	185.7
BECP Total				
Annual in 2040	1.2	2.2	2.3	5.2
Cumulative 1992−2040	24.0	44.1	45.7	230.3

(a) Site energy savings represent direct energy savings to the consumer. Site energy savings multiplied by the energy price represent energy cost savings to the consumer.

(b) Following the analysis methodology used by DOE's Appliance and Equipment Standards Program, site energy savings were first converted to the source energy terms, which includes energy used in generation, transmission, and distribution (primary energy).

(c) Energy used further "upstream" in the mining, processing, and transportation of fuels cycle was calculated using the NIA PLUS model and added to the primary energy savings to yield full-fuel-cycle (FFC) energy savings.

Table 5.2. Breakdown of BECP Energy and Cost Savings between Commercial and Residential Activities (quads)

	Site Energy Savings,[a] quads	Primary Energy Savings,[b] quads	FFC Energy Savings,[c] quads	Energy Cost Savings NPV, billion 2012$
Historical				
Annual in 2012				
Commercial	0.2	0.3	0.3	3.3
Residential	0.1	0.1	0.2	1.7
Cumulative 1992−2012				
Commercial	1.2	2.8	2.8	29.0
Residential	0.7	1.3	1.4	15.6
Projected				
Annual in 2040				
Commercial	0.7	1.3	1.3	2.9
Residential	0.5	0.9	0.9	2.3
Cumulative 2013−2040				
Commercial	12.6	24.2	25.0	106.1
Residential	9.4	15.9	16.6	79.6
BECP Total				
Annual in 2040				
Commercial	0.7	1.3	1.3	2.9
Residential	0.5	0.9	0.9	2.3
Cumulative 1992−2040				
Commercial	13.8	27.0	27.8	135.1
Residential	10.2	17.2	17.9	95.2

(a) Site energy savings represent direct energy savings to the consumer. Site energy savings multiplied by the energy price represent energy cost savings to the consumer.

(b) Following the analysis methodology used by DOE's Appliance and Equipment Standards Program, site energy savings were first converted to the source energy terms, which includes energy used in generation, transmission, and distribution (primary energy).

(c) Energy used further "upstream" in the mining, processing, and transportation of fuels cycle was calculated using the NIA PLUS model and added to the primary energy savings to yield full-fuel-cycle (FFC) energy savings.

Detailed annual primary energy savings and FFC energy savings are presented in Table 5.3 and Table 5.4, respectively.

Table 5.3. BECP Historical and Projected Primary Energy Savings (quads)

	Annual Primary quads	Cumulative Primary quads	Annual	Cumulative
			Post 2012 construction only	
1992	0.00	0.00		
1993	0.01	0.01		
1994	0.01	0.02		
1995	0.01	0.03		
1996	0.02	0.05		
1997	0.04	0.09		
1998	0.05	0.14		
1999	0.06	0.20		
2000	0.08	0.28		
2001	0.11	0.39		
2002	0.15	0.54		
2003	0.19	0.73		
2004	0.23	0.96		
2005	0.27	1.23		
2006	0.31	1.54		
2007	0.35	1.88		
2008	0.38	2.26		
2009	0.41	2.67		
2010	0.43	3.11		
2011	0.45	3.56		
2012	0.48	4.04		
2013	0.53	4.58	0.05	0.05
2014	0.57	5.15	0.09	0.13
2015	0.62	5.76	0.13	0.27
2016	0.71	6.47	0.23	0.49
2017	0.79	7.27	0.31	0.80
2018	0.87	8.14	0.39	1.19
2019	0.99	9.13	0.50	1.69
2020	1.10	10.22	0.61	2.30
2021	1.13	11.35	0.64	2.94
2022	1.22	12.57	0.73	3.68
2023	1.31	13.87	0.82	4.50
2024	1.39	15.27	0.91	5.41
2025	1.47	16.74	0.99	6.39
2026	1.44	18.18	0.96	7.35
2027	1.51	19.69	1.02	8.38
2028	1.57	21.26	1.09	9.46
2029	1.64	22.90	1.15	10.61
2030	1.70	24.59	1.21	11.83
2031	1.71	26.30	1.23	13.05
2032	1.77	28.07	1.28	14.34
2033	1.83	29.90	1.34	15.68
2034	1.88	31.78	1.40	17.08
2035	1.93	33.72	1.45	18.53
2036	1.99	35.70	1.50	20.03
2037	2.04	37.74	1.55	21.58
2038	2.08	39.82	1.60	23.18
2039	2.13	41.95	1.65	24.83
2040	2.18	44.13	1.69	26.52

Table 5.4. BECP Historical and Projected Full-Fuel-Cycle Energy Savings (quads)

	Annual FFC quads	Cumulative FFC quads	Total, Annual Post 2012 construction only	Total, Cumulative Post 2012 construction only
1992	0.0	0.0		
1993	0.0	0.0		
1994	0.0	0.0		
1995	0.0	0.0		
1996	0.0	0.1		
1997	0.0	0.1		
1998	0.1	0.1		
1999	0.1	0.2		
2000	0.1	0.3		
2001	0.1	0.4		
2002	0.2	0.6		
2003	0.2	0.8		
2004	0.2	1.0		
2005	0.3	1.3		
2006	0.3	1.6		
2007	0.4	1.9		
2008	0.4	2.3		
2009	0.4	2.8		
2010	0.4	3.2		
2011	0.5	3.7		
2012	0.5	4.2		
2013	0.5	4.7	0.0	0.0
2014	0.6	5.3	0.1	0.1
2015	0.6	6.0	0.1	0.3
2016	0.7	6.7	0.2	0.5
2017	0.8	7.5	0.3	0.8
2018	0.9	8.4	0.4	1.2
2019	1.0	9.4	0.5	1.7
2020	1.1	10.6	0.6	2.4
2021	1.2	11.7	0.7	3.0
2022	1.3	13.0	0.8	3.8
2023	1.4	14.3	0.9	4.7
2024	1.4	15.8	0.9	5.6
2025	1.5	17.3	1.0	6.6
2026	1.5	18.8	1.0	7.6
2027	1.6	20.4	1.1	8.7
2028	1.6	22.0	1.1	9.8
2029	1.7	23.7	1.2	11.0
2030	1.8	25.5	1.3	12.3
2031	1.8	27.2	1.3	13.5
2032	1.8	29.1	1.3	14.9
2033	1.9	31.0	1.4	16.3
2034	2.0	32.9	1.5	17.7
2035	2.0	34.9	1.5	19.2
2036	2.1	37.0	1.6	20.8
2037	2.1	39.1	1.6	22.4
2038	2.2	41.3	1.7	24.1
2039	2.2	43.5	1.7	25.8
2040	2.3	45.7	1.8	27.5

A summary of emissions savings from BECP energy code activities calculated based on the FFC analysis is presented in Table 5.5.

Table 5.5. Summary of Emissions Savings from BECP Energy Code Activities

	CO_2 (mmt)	NO_x (kt)	Hg (ton)	N_2O (kt)	N_2O (mmt CO_2eq)	CH_4 (kt)	CH_4 (mmt CO_2eq)	SO_2 (kt)
Historical								
Annual in 2012	36	80	0.1	0.4	0.1	159	4	46
Cumulative 1992–2012	300	664	0.6	3.3	1.0	1,347	34	386
Projected, 2013−2040 Construction								
Annual in 2040	185	194	0.4	1.8	0.5	796	20	116
Cumulative 2013–2040	3,178	3,855	6.9	32.1	9.6	14,095	352	3,489
BECP Total								
Annual in 2040	185	194	0.4	1.8	0.5	796	20	116
Cumulative 1992–2040	3,478	4,519	7.6	35.4	10.5	15,441	386	3,875

Cumulative emissions reductions between 1992 and 2040 include almost 3.5 billion metric tons (Mt) of CO_2, 4.5 million tons of NO_x, 7.6 tons of Hg, and 3.9 million tons of SO_2.

The value of the CO_2 emission reductions is $2.0 to $6.4 billion (2012$) based on 2013 domestic social carbon values and a 5% discount rate, or $28 billion based on 2013 global SCC, while NO_x savings contribute at least another $1.1 billion of savings (at $468 per ton in 2012$). Energy cost savings presented in Table 5.1, combined with physical and monetized emission savings presented in Table 5.5, capture consumer benefits to the nation from the BECP energy code activities.

Combined consumer benefits from BECP activities are shown in Table 5.6 and Table 5.7. Depending on the price of CO_2 and NO_x, the NPV of overall consumer benefits can range between $259 and almost $594 billion (2012$). Out of that total, the energy cost savings constitute $230 billion (2012$).

Table 5.6. National Benefits from BECP Energy Code Activities, 1992–2040

Cumulative Results	Units	Commercial (1992-2040)	Residential (1992-2040)	Total BECP (1992-2040)
Energy Savings				
Site	quads	13.8	10.2	24.0
Primary	quads	27.0	17.2	44.1
Full-Fuel-Cycle (total)	quads	27.8	17.9	45.7
Economic Impacts				
Energy Cost Savings	billion 2012$	135	95	230
Emissions Savings (physical)				
Full-Fuel-Cycle (total)				
CO_2	mmt	2,138	1,339	3,478
NO_x	kt	2,699	1,821	4,519
Hg	ton	4.8	2.8	8
N_2O	kt	23.1	12.3	35
N_2O	mmt CO_2eq	6.9	3.7	11
CH_4	kt	8,945	6,497	15,441
CH_4	mmt CO_2eq	224	162	386
SO_2	kt	2,742	1,133	3,875

Table 5.6. (contd)

Cumulative Results	Units	Commercial (1992-2040)	Residential (1992-2040)	Total BECP (1992-2040)
Emissions Savings (monetized)				
Full-Fuel-Cycle (total)				
CO_2 (global)				
5% discount rate, average	billion 2012$	17.3	10.6	28.0
3% discount rate, average	billion 2012$	71.3	44.4	115.7
2.5% discount rate, average	billion 2012$	112.6	70.2	182.8
3% discount rate, 95th %ile	billion 2012$	216.8	135.7	352.6
CO_2 (domestic)				
5% discount rate, average	billion 2012$	1.2 to 4	0.7 to 2.4	2 to 6.4
3% discount rate, average	billion 2012$	5 to 16.4	3.1 to 10.2	8.1 to 26.6
2.5% discount rate, average	billion 2012$	7.9 to 25.9	4.9 to 16.1	12.8 to 42
3% discount rate, 95th %ile	billion 2012$	15.2 to 49.9	9.5 to 31.2	24.7 to 81.1
NO_x (7% discount rate)				
At 468 2012$/ton	billion 2012$	0.7	0.4	1.1
At 2,639 2012$/ton	billion 2012$	3.8	2.3	6.0
At 4,809 2012$/ton	billion 2012$	6.9	4.1	11.0

Each one of the consumer and emissions value estimates shown in Table 5.7 represent a combination of consumer energy cost savings, and corresponding scenarios for monetized reduction of CO_2 and NOx. For example, Consumers + CO_2 (1st) + NO_x (Low) means that savings from the first scenario of CO_2 (5% discount rate, average, global SCC) were combined with savings from the low NO_x cost scenario (at $468 per ton in 2012$) and added to the consumer energy cost savings.

Table 5.7. Consumer Cumulative Benefits of the BECP Activities, 1992–2040

Cumulative Results		Commercial (1992–2040)	Residential (1992–2040)	Total BECP (1992–2040)
NPV				
Consumer Energy Cost Savings	billion 2012$	135	95	230
Consumer and Emissions Value				
Consumers + CO_2 (1st) + NO_x (Low)	billion 2012$	153	106	259
Consumers + CO_2 (2nd) + NO_x (Med)	billion 2012$	210	142	352
Consumers + CO_2 (3rd) + NO_x (Med)	billion 2012$	251	168	419
Consumers + CO_2 (4th) + NO_x (High)	billion 2012$	359	235	594

The estimated cumulative benefits from the Program through 2040 are significant. The cumulative energy savings attributed from the Program total nearly 46 quads of FFC energy, or 44 quads of primary energy, equivalent to almost an entire year's worth of primary energy consumption from the U.S. residential and commercial sectors at current consumption rates. The Program may save consumers up to $230 billion on their utility bills by 2040. Annual carbon savings reach 36 million tons at the end of 2012 and the cumulative savings by 2040 are estimated at 3,478 million tons.

Finally, BECP's cumulative FFC savings of emissions of CO_2, N_2O, and CH_4 in CO_2-equivalents in Table ES.2 are almost 3.9 billion metric tons. That is equivalent to three-quarters of all energy-related emissions of the United States in 2012. These benefits do not count the reduction of other energy-related air pollutants shown in Table ES.2, or billions of dollars in saved future investment in facilities to supply the natural gas, electricity, and fuel oil to the residential and commercial sectors that would not be needed. BECP efforts clearly make a difference to the economy and citizens of the United States.

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Appendix

Energy Savings Potential from More Rapid Code Adoption and Compliance, 2013–2040

Appendix

Energy Savings Potential from More Rapid Code Adoption and Compliance, 2013–2040

This appendix contains an estimate of the potential energy savings for residential and commercial code activities assuming immediate adoption and full compliance for 2013–2040. The objective of this analysis was to estimate energy, cost, and emissions that could be saved on post-2013 construction under ideal adoption and compliance conditions. We modeled this situation with an "immediate adoption" scenario, which also included 100% immediate compliance. The stream of future savings in this scenario corresponded to Stream 2 in the projected savings presented in the results section of the main report (Section 5, Table 5.1).

The methodology for estimating the potential is the same as outlined in Section 2.0 of the report in the sense that we compared two scenarios. Potential savings were calculated as a difference between energy consumption in a base case scenario and energy consumption in the immediate adoption scenario. Separate sets of adoption and compliance assumptions were developed to characterize the base case and immediate adoption scenarios.

The common starting point for adoption for both scenarios was the most recent energy code version adopted in each state (explicitly or implicitly) in 2013. In the base case it was assumed that no further code versions were adopted thereafter.

The immediate adoption scenario assumed that for all code versions starting with IECC 2012/90.1-2007, the adoption occurred in the year following the publication year of the code (code version + 1 year lag). Thus, the IECC 2012 code would be adopted in 2013. This means that the ideal "immediate" adoption path was compared against the adoption status at the beginning of the analysis period. The code adoption assumptions for commercial and residential energy codes are summarized in Table A.1 and Table A.2.

In the immediate adoption scenario, initial compliance was set at 100% for all states in the year of adoption, including the states with no statewide code and home-rule states. This was consistent with the context of this analysis where the ideal compliance path was compared with the compliance status at the beginning of the analysis period.

In the base case scenario, compliance with the adopted code was assumed to be lower/delayed. In the base case, the same state classifications were used for commercial and residential energy codes as shown in Table 3.7 of Section 3 and Table 4.5 of Section 4. As a result, base case assumptions for initial compliance were set to equal compliance rates for the "without BECP" scenario outlined in Table 3.10 and Table 3.11 of Section 3, and Table 4.8 and Table 4.9 of Section 4.

California, Florida, Oregon, and Washington were included in this analysis because energy savings potential was attribution-free and represented total savings available from code activities between 2013 and 2040.

Table A.1. Base Case and Immediate Adoption Scenario, Commercial Energy Codes

	Starting Point Code in Effect in 2013	Base case	Immediate Adoption*					
			90.1-2010*	**90.1-2013***	**90.1-2016***	**90.1-2019***	**90.1-2022***	**90.1-2025***
Alabama	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Alaska	90.1-1999/2001	No Change	2013	2016	2019	2022	2025	2028
Arizona	90.1-1999/2001	No Change	2013	2016	2019	2022	2025	2028
Arkansas	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
California	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Colorado	90.1-2004	No Change	2013	2016	2019	2022	2025	2028
Connecticut	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Delaware	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
District of Columbia	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Florida	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Georgia	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Hawaii	90.1-2004	No Change	2013	2016	2019	2022	2025	2028
Idaho	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Illinois	90.1-2010	No Change	2013	2016	2019	2022	2025	2028
Indiana	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Iowa	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Kansas	90.1-1999/2001	No Change	2013	2016	2019	2022	2025	2028
Kentucky	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Louisiana	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Maine	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Maryland	90.1-2010	No Change	2012	2016	2019	2022	2025	2028
Massachusetts	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Michigan	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Minnesota	90.1-2004	No Change	2013	2016	2019	2022	2025	2028
Mississippi	90.1-1999/2001	No Change	2013	2016	2019	2022	2025	2028
Missouri	90.1-2010	No Change	2013	2016	2019	2022	2025	2028
Montana	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Nebraska	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Nevada	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
New Hampshire	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
New Jersey	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
New Mexico	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
New York	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
North Carolina	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
North Dakota	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Ohio	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Oklahoma	90.1-2004	No Change	2013	2016	2019	2022	2025	2028
Oregon	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Pennsylvania	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Rhode Island	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
South Carolina	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
South Dakota	90.1-1999/2001	No Change	2013	2016	2019	2022	2025	2028
Tennessee	90.1-2004	No Change	2013	2016	2019	2022	2025	2028
Texas	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Utah	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Vermont	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Virginia	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Washington	90.1-2010	No Change	2013	2016	2019	2022	2025	2028
West Virginia	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Wisconsin	90.1-2007	No Change	2013	2016	2019	2022	2025	2028
Wyoming	90.1-1999/2001	No Change	2013	2016	2019	2022	2025	2028

*Because states typically adopt the IECC and then by reference in the IECC automatically get Standard 90.1, the adoption assumption tables show the adopted versions of the IECC for residential and reference versions of Standard 90.1 for commercial. A one year lag is added to the IECC code version year. Thus Standard 90.1-2010 would be adopted in 2013.

Table A.2. Base Case and Immediate Adoption Scenario, Residential Energy Codes

	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

Table A.3 through Table A.7 show potential projected energy savings, energy cost savings, emissions reductions, and monetized emissions savings assuming immediate adoption and 100% compliance.

Potential code-induced energy savings and energy cost savings are presented in Table A.3. Cumulative site energy savings potential equals 36 quads, with residential and commercial energy code activities contributing approximately 50% each. Primary energy savings potential is 64.7 quads, which translates to FFC energy savings of 67 quads. Cumulative energy cost savings potential equals approximately $261.5 billion (2012$).

Table A.3. Summary of Energy and Cost Savings Potential

	Site Energy Savings, quads	**Primary Energy Savings, quads**	**FFC Energy Savings, quads**	**Energy Cost Savings NPV, billion 2012$ (7% discount rate)**
Potential Savings, Commercial				
Annual in 2040	1.6	2.9	3.0	6.6
Cumulative 2013–2040	18.9	36.3	37.4	134.5
Potential Savings, Residential				
Annual in 2040	1.3	2.1	2.2	5.4
Cumulative 2013–2040	17.2	28.3	29.6	127.1
Potential Savings, Total				
Annual in 2040	2.8	5.0	5.2	12.0
Cumulative 2013–2040	36.1	64.7	67.0	261.5

Detailed annual site energy savings potential, primary energy savings potential, and FFC energy savings potential are presented in Table A.4.

Table A.4. Potential Site, Primary, and FFC Energy Savings (quads)

	Site Annual, quads	**Site Cumulative, quads**	**Primary Annual, quads**	**Primary Cumulative, quads**	**FFC Annual, quads**	**FFC Cumulative, quads**
2013	0.04	0.04	0.08	0.08	0.1	0.1
2014	0.09	0.13	0.18	0.25	0.2	0.3
2015	0.15	0.28	0.29	0.54	0.3	0.6
2016	0.23	0.50	0.44	0.99	0.5	1.0
2017	0.30	0.81	0.60	1.59	0.6	1.6
2018	0.38	1.19	0.76	2.35	0.8	2.4
2019	0.47	1.67	0.94	3.30	1.0	3.4
2020	0.56	2.23	1.12	4.42	1.2	4.6
2021	0.65	2.88	1.22	5.64	1.3	5.8
2022	0.75	3.62	1.41	7.04	1.5	7.3
2023	0.84	4.47	1.59	8.64	1.7	8.9
2024	0.94	5.41	1.79	10.42	1.8	10.8
2025	1.05	6.46	2.00	12.42	2.1	12.9
2026	1.16	7.63	2.07	14.50	2.2	15.0
2027	1.27	8.90	2.27	16.76	2.4	17.4
2028	1.38	10.28	2.47	19.24	2.6	19.9
2029	1.50	11.78	2.68	21.92	2.8	22.7
2030	1.61	13.39	2.88	24.80	3.0	25.7
2031	1.72	15.12	3.01	27.81	3.1	28.8

Table A.4. (contd)

	Site Annual, quads	Site Cumulative, quads	Primary Annual, quads	Primary Cumulative, quads	FFC Annual, quads	FFC Cumulative, quads
2032	1.84	16.96	3.22	31.03	3.3	32.2
2033	1.96	18.91	3.42	34.45	3.6	35.7
2034	2.08	20.99	3.64	38.09	3.8	39.5
2035	2.20	23.19	3.86	41.95	4.0	43.5
2036	2.33	25.52	4.08	46.04	4.2	47.7
2037	2.46	27.98	4.31	50.35	4.5	52.2
2038	2.58	30.56	4.54	54.89	4.7	56.9
2039	2.71	33.27	4.77	59.65	4.9	61.9
2040	2.84	36.11	4.99	64.65	5.2	67.0

A summary of emissions reduction potential calculated based on the FFC analysis is presented in Table A.5.

Table A.5. Summary of Emissions Reduction Potential

	CO_2 mmt	NO_x kt	Hg ton	N_2O kt	N_2O mmt CO_2eq	CH_4 kt	CH_4 mmt CO_2eq	SO_2 kt
Potential Reduction, Commercial								
Annual in 2040	252	243	0.6	2.7	0.8	1,005	25.1	151
Cumulative 2013–2040	2,980	3,069	6.7	32.4	9.6	12,118	303	3,180
Potential Reduction, Residential								
Annual in 2040	174	200	0.4	1.5	0.4	809	20.2	118
Cumulative 2013–2040	2,251	2,790	4.9	20.1	6.0	10,971	274	1,711
Potential Reduction, Total								
Annual in 2040	426	443	1.0	4.2	1.2	1,814	45	269
Cumulative 2013–2040	5,230	5,859	11.6	52.5	15.6	23,089	577	4,891

Cumulative emissions reductions potential between 2013 and 2040 includes over 5.2 billion metric tons (Mt) of CO_2, nearly 5.9 million tons of NO_x, 11.6 tons of Hg, and nearly 4.9 million tons of SO_2.

The value of the CO_2 emissions reductions is \$2.7 to \$8.8 billion (2012\$) based on 2013 domestic social carbon values and a 5% discount rate, or 38.5 billion (2012\$) based on global SCC. While at the low-end of a range of values, NO_x savings contribute at least another \$0.9 billion of savings (at \$468 per ton in 2012\$). Energy cost savings potential presented in Table A.3, combined with the physical and monetized emission savings potential presented in Table A.6, capture potential consumer benefits to the nation from the energy code activities between 2013 and 2040, assuming immediate adoption and full compliance.

The combined consumer benefits potential is shown in Table A.7. Depending on the social cost of CO_2 and NO_x, the NPV of potential consumer benefits can range between \$301 and nearly \$796 billion (2012\$). Out of that total, the energy cost savings potential exceeds \$261 billion (2012\$).

Each one of the consumer and emissions value estimates shown in Table A.7 represent a combination of consumer energy cost savings, and corresponding scenarios for monetized reduction of CO_2 and NO_x. For example, Consumers + CO_2 (1st) + NO_x (Low) means that savings from the first scenario of CO_2 (5%

discount rate, average, global SCC) were combined with savings from the low NO_x cost scenario (at $468 per ton in 2012$) and added to the consumer energy cost savings.

Table A.6. National Benefits Potential, 2013–2040

Cumulative Results	Units	Commercial (2013-2040)	Residential (2013-2040)	Total BECP (2013-2040)
Energy Savings				
Site	quads	36.3	28.3	64.6
Primary	quads	1.1	1.3	2.4
Full-Fuel-Cycle (total)	quads	37.4	29.6	67.0
Economic Impacts				
Potential Energy Cost Savings, 7 % discount rate	billion 2012$	134.5	127.1	261.5
Emissions Savings (physical)				
Full-Fuel-Cycle (total)				
CO_2	mmt	2,980	2,251	5,230
NO_x	kt	3,069	2,790	5,859
Hg	ton	6.7	4.9	12
N_2O	kt	32.4	20.1	53
N_2O	mmt CO_2eq	9.6	6.0	16
CH_4	kt	12,118	10,971	23,089
CH_4	mmt CO_2eq	303	274	577
SO_2	kt	3,180	1,711	4,891
Emissions Savings (monetized)				
Full-Fuel-Cycle (total)				
CO_2 (global)				
5% discount rate, average	billion 2012$	21.8	16.7	38.5
3% discount rate, average	billion 2012$	96.7	73.4	170.1
2.5% discount rate, average	billion 2012$	153.1	116.1	269.2
3% discount rate, 95th %ile	billion 2012$	298.8	226.6	525.4
CO_2 (domestic)				
5% discount rate, average	billion 2012$	1.5 to 5	1.2 to 3.8	2.7 to 8.8
3% discount rate, average	billion 2012$	6.8 to 22.2	5.1 to 16.9	11.9 to 39.1
2.5% discount rate, average	billion 2012$	10.7 to 35.2	8.1 to 26.7	18.8 to 61.9
3% discount rate, 95th %ile	billion 2012$	20.9 to 68.7	15.9 to 52.1	36.8 to 120.8
NO_x (7% discount rate)				
At 468 2012$/ton	billion 2012$	0.47	0.4	0.9
At 2,639 2012$/ton	billion 2012$	2.6	2.5	5.1
At 4,809 2012$/ton	billion 2012$	4.8	4.5	9.3

Table A.7. Consumer Cumulative Benefits Potential, 2013–2040

Cumulative Results		Commercial (2013-2040)	Residential (2013-2040)	Total BECP (2013-2040)
NPV				
Consumer Energy Cost Savings	billion 2012$	134.5	127.1	261.5
Consumer and Emissions Value				
Consumers + CO_2 (1st) + NO_x (Low)	billion 2012$	157	144	301
Consumers + CO_2 (2nd) + NO_x (Med)	billion 2012$	234	203	437
Consumers + CO_2 (3rd) + NO_x (Med)	billion 2012$	290	246	536
Consumers + CO_2 (4th) + NO_x (High)	billion 2012$	438	358	796

Combining potential energy savings from new post-2013 construction with code-induced savings from existing stock that keep occurring in 2013–2040 represents the full future potential of the energy codes activities. These results are summarized in Table A.8 and Table A.9.

Table A.8. Summary of Full Future Energy and Cost Savings Potential

	Site Energy Savings, quads	Primary Energy Savings, quads	FFC Energy Savings, quads	Energy Cost Savings NPV, billion 2012$ (7% discount rate)
Potential Savings, Commercial				
Annual in 2040	1.7	3.2	3.3	7.2
Cumulative 2013–2040	23.1	44.8	46.2	178.8
Potential Savings, Residential				
Annual in 2040	1.4	2.2	2.3	5.8
Cumulative 2013–2040	19.5	32.2	33.8	150.9
Potential Savings, Total				
Annual in 2040	3.1	5.4	5.6	13.0
Cumulative 2013–2040	42.6	77.0	80.0	329.7

Table A.9. Summary of Full Future Emissions Reduction Potential

	CO_2 mmt	NO_x kt	Hg Ton	N_2O kt	N_2O mmt CO_2eq	CH_4 kt	CH_4 mmt CO_2eq	SO_2 kt
Potential Reduction, Total								
Annual in 2040	461	479	1.1	4.5	1.3	1,962	49	291
Cumulative 2013–2040	6,189	7,178	13.7	62.3	18.6	27,280	682	6,140

Full cumulative site energy savings potential for 2013–2040 equals 42.6 quads, with residential and commercial energy code activities contributing approximately 50% each. Primary energy savings potential is 77 quads, which translates to FFC energy savings of nearly 80 quads. Cumulative energy cost savings potential equals approximately $330 billion (2012$). Annual carbon savings potential reaches 461 million tons at the end of 2040, and the cumulative potential carbon savings by 2040 are estimated at nearly 6.2 billion tons.

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