Change Is in the Air: How States Can Harness Energy Efficiency to Strengthen the Economy and Reduce Pollution

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Executive Summary

THE OPPORTUNITY

On June 25, 2013 President Obama called on the U.S. Environmental Protection Agency (EPA) to regulate greenhouse gases from existing power plants. Section 111(d) of the Clean Air Act is the authority on which EPA will base the rule. Several questions that bear on the final rule are still outstanding. How much can we reduce greenhouse gas emissions? At what cost? How readily will states be able to implement these solutions? The language in Section 111(d) gives EPA broad authority, including the opportunity to consider flexible compliance strategies to meet emissions standards. One of the most promising compliance strategies for low-cost pollution abatement is end-use energy efficiency.

In evaluating what the power sector as a whole can achieve, EPA should recognize the leadership the states have already shown in developing their energy efficiency resources rather than imposing an entirely new set of administrative requirements on them. EPA should include efficiency's potential to reduce pollution when setting the emissions standard and allow end-use energy efficiency to qualify as a compliance mechanism in the upcoming regulation. This will help states and the power sector take advantage of the lowest-cost approach to reducing greenhouse gas emissions.

States are ultimately responsible for developing and implementing Section 111(d) plans to reduce carbon dioxide from existing power plants. Together they have decades of experience in successfully implementing—and rigorously measuring and quantifying—efficiency policies and programs as part of the system that meets their power sector demands. They will be able to build on this experience as they tap the substantial efficiency opportunities that remain.

THE APPROACH

This study evaluates the implications of using end-use energy efficiency to reduce greenhouse gas emissions from the power sector. It does so by quantifying the energy, economic, and pollution-reduction impacts of selected energy-saving policies on a state-by-state basis. We evaluate four of the most common and effective energy efficiency policy options available to a state:

- Implement an energy efficiency savings target
- Enact national model building codes
- Construct combined heat and power systems
- Adopt efficiency standards for products/equipment

We assume a scenario in which a state adopts these four policies, and then we quantify the resulting impacts. We rely on actual state experience to estimate the policies' impacts on electricity consumption, the environment, the economy, and jobs. Our findings suggest the minimum amount of CO_2 reductions that could be cost effectively achieved.

Our analysis is not a forecast of what will happen, but a description of the energy, environmental, and economic outcomes of using end-use efficiency in the context of Section 111(d) to reduce greenhouse gases from the power sector. Since we quantify only a subset of the efficiency potential that exists in the states, our results represent a smaller set of savings than what might be addressed in a potential study that considers what is economically or technically achievable.[1] Our analysis is limited to conservative assumptions and adequately demonstrated practices and technologies. All states can readily achieve the levels of energy efficiency we describe.

THE RESULTS

If every state adopted the four policies in our scenario, in 2030 carbon dioxide emissions from the power sector would be reduced by 26% relative to 2012 emissions, and power demand would be reduced by 25% relative to 2012. The nation would avoid 600 million tons of carbon dioxide emissions, save over 925 million MWh of electricity, and obviate the need for 494 power plants in 2030.[2]

Our analysis finds that all states would also enjoy considerable economic and environmental benefits under our scenario, since each of them has a great deal of untapped efficiency potential. Table E1 lists the percentage reduction in electricity consumption that each state would achieve in 2030 relative to 2012.

Table E1. Percentage reduction in electricity consumption in 2030 relative to 2012 baseline

Alabama	22%	Kentucky	22%	North Dakota	21%
Alaska	35%	Louisiana	26%	Ohio	23%
Arizona	39%	Maine	26%	Oklahoma	22%
Arkansas	22%	Maryland	23%	Oregon	27%
California	28%	Massachusetts	32%	Pennsylvania	23%
Colorado	28%	Michigan	21%	Rhode Island	25%
Connecticut	30%	Minnesota	24%	South Carolina	24%
Delaware	23%	Mississippi	24%	South Dakota	20%
District of Columbia	26%	Missouri	21%	Tennessee	26%
Florida	25%	Montana	23%	Texas	25%
Georgia	24%	Nebraska	19%	Utah	27%
Hawaii	36%	Nevada	24%	Vermont	28%
Idaho	23%	New Hampshire	31%	Virginia	23%
Illinois	23%	New Jersey	27%	Washington	23%
Indiana	22%	New Mexico	30%	West Virginia	23%
Iowa	25%	New York	37%	Wisconsin	24%
Kansas	23%	North Carolina	24%	Wyoming	25%

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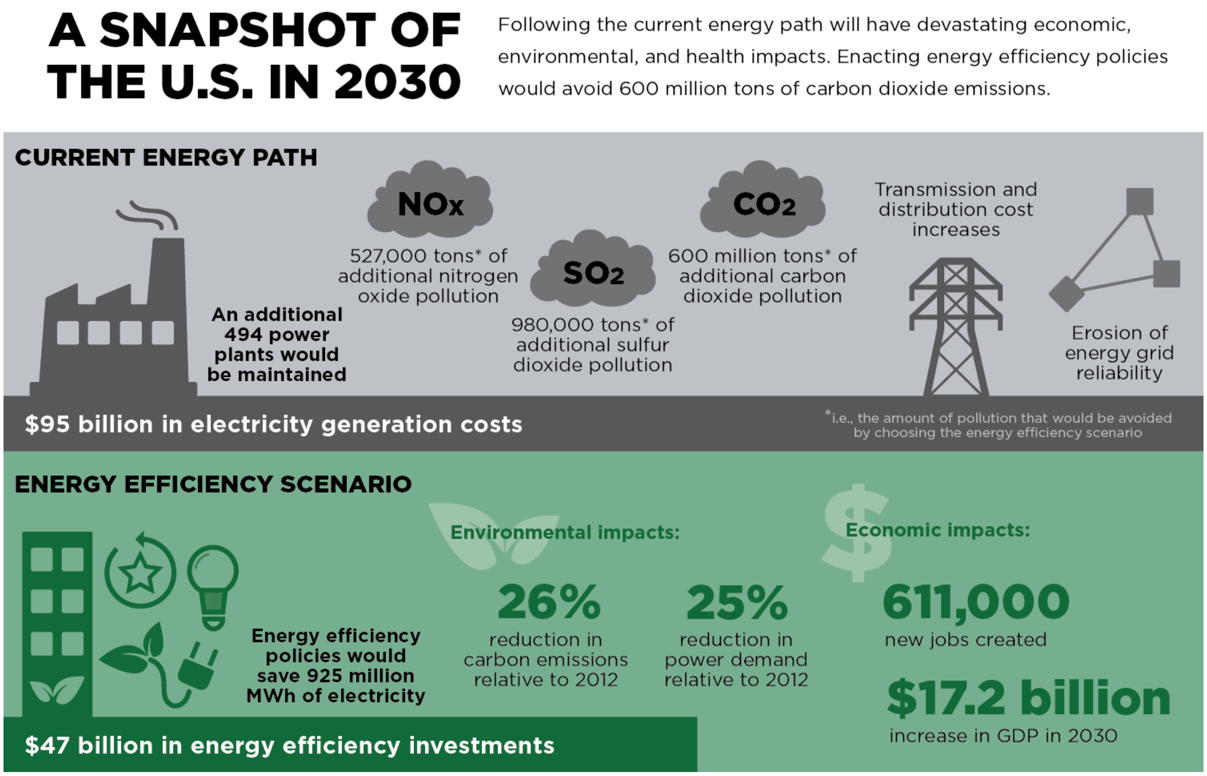
[1] This analysis also does not include the many additional resources states might use to reduce greenhouse gas emissions, such as renewable energy, efficiency upgrades at the power generator, fuel switching, and dispatch shifting.

[2] Based on 500 MW and assuming the national average capacity factor (45%) and 5% line losses.

What would it cost to adopt these policies? It would cost less than business as usual and, since energy efficiency simultaneously meets electricity demand and reduces pollution, it would cost much less than meeting demand and reducing greenhouse gas emissions separately. Energy efficiency is a low-cost solution to multiple challenges. It helps maintain electric system reliability as old power plants retire, meets demand without the expense of building new power plants, and avoids expensive emission control technologies that would needed to keep older, inefficient power plants operating.

Our efficiency scenario would increase national gross domestic product by $17.2 billion in 2030 and produce a net gain of about 611,000 jobs. It would also improve states' economic outlook. While the impact on jobs is larger in some states than others, all 50 states would see net job creation.

Figure E1 compares some of the benefits and costs of a future with energy efficiency policies and one without.



A SNAPSHOT OF THE U.S. IN 2030

Following the current energy path will have devastating economic, environmental, and health impacts. Enacting energy efficiency policies would avoid 600 million tons of carbon dioxide emissions.

Figure E1. Current U.S. energy path versus energy efficiency scenario

CONCLUSIONS

There has been a great deal of speculation about how a Section 111(d) rule should be structured, what it could achieve, and what the impacts of regulation might be on the economy. Our analysis shows the following:

1. An emissions standard set at 26% below 2012 levels can be achieved at no net cost to the economy. This standard will create 611,000 new jobs, and it will have a positive economic impact on the country.

2. The U.S. power sector can significantly reduce greenhouse gases while states maintain the flexibility to make use of all of their energy resources.

3. The policies and technologies included in our analysis have already been tested and are deployable now. The benefits can be quantified. There is no need to delay.

It is also important to note that while end-use energy efficiency has long been cost effective, regulatory and market barriers continue to inhibit increased investments in efficiency policies and programs. Not only should a rulemaking that limits greenhouse gas emissions recognize the emissions benefits of energy efficiency, but it should also be stringent enough to overcome existing market barriers. A rule that sets a weak standard or does not clear the path for efficiency would leave states with more expensive compliance options. As a result, the nation would lose out on the economic benefits we describe.

The United States is a large country with a diversity of natural resources. Some states have coal, while others make use of hydropower, nuclear, wind, or natural gas. Energy efficiency gives states the flexibility to take advantage of the full range of their natural resources while also reducing pollution. It is the one resource they cannot afford to ignore.

Introduction

CHANGE IS IN THE AIR

On June 25, 2013 President Obama called on the U.S. Environmental Protection Agency (EPA) to regulate greenhouse gases from existing power plants. Section 111(d) of the Clean Air Act is the authority on which EPA will base the rule. Several questions that bear on the final rule are still outstanding. How much can we reduce greenhouse gas emissions? At what cost? How readily will states be able to implement these solutions? The language in Section 111(d) gives EPA broad authority, including the opportunity to consider flexible compliance strategies to meet emissions standards. One of the most promising compliance strategies for low-cost pollution abatement is end-use energy efficiency.

THE INTERSECTION OF AIR REGULATIONS AND ENERGY EFFICIENCY

The energy savings from end-use efficiency measures have already resulted in significant cost-effective greenhouse gas emission reductions from the electric power sector.[3] While there is little precedent for applying energy efficiency to Section 111(d) specifically, EPA guidance on other existing Clean Air Act programs includes a role for efficiency and suggests its potential as a Section 111(d) compliance option. The Acid Rain Trading Program, NO_x SIP Call, New Source Review, and State Implementation Plans for National Ambient Air Quality Standards have all incorporated energy efficiency as a compliance mechanism.[4] In fact the EPA and Congress originally provided for energy efficiency as a means to meet certain air emission requirements over 20 years ago (EPA 1999).

The upcoming rulemaking gives EPA an opportunity to once again allow flexible compliance strategies such as end-use efficiency. Section 111(d) requires EPA to set the standard to reflect the emissions limits achievable through the "best system of emission reduction which . . . has been adequately demonstrated" [42 USC § 7411 (a) (1)]. In fact, states, utilities, grid operators, and others have for decades relied on end-use energy efficiency policies and programs for financial, legal, economic development, and environmental purposes. This experience clearly shows that end-use energy efficiency has been adequately demonstrated.

The relevant section of the Clean Air Act uses a multi-factor balancing test which, among other things, requires EPA to consider costs associated with the system of emission reductions. Given the low cost and widespread availability of end-use energy efficiency, it should play a major role in EPA's forthcoming rulemaking.[5]

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[3] We include combined heat and power (CHP) in our discussion of end-use energy efficiency throughout this document.

[4] For an overview of this history see Hayes and Young 2012, and Tarr, Monast, and Profeta 2013.

[5] The application of Section 111(d) has been limited, causing some to question whether there are limits on the role end-use energy efficiency may play in a rulemaking. For a discussion of the legal issues surrounding the treatment of efficiency in Section 111(d) see Konschnik and Peskoe (2014).

EPA should factor in the emissions reduction potential of end-use energy efficiency as it sets the stringency of the standard under Section 111(d). This will help ensure that the rule achieves meaningful emission reductions from the power sector. In addition, by including efficiency as a compliance mechanism, EPA will allow the power sector to use the lowest-cost approaches to achieve the required reductions. In a world where greenhouse gas emissions must be reduced, end-use energy efficiency is a resource EPA and the states cannot afford to ignore.

ENORMOUS POTENTIAL TO REDUCE POLLUTION AT LEAST COST

Beginning in the 1970s, energy efficiency has quietly become our nation's most abundant energy resource. End-use efficiency has been largely responsible for reducing U.S. energy use by more than 50% relative to what it would have been if pre-1973 trends had continued. Coupled with structural changes in the economy, improvements in energy efficiency have supplied more energy than domestic coal, natural gas, and oil combined (Laitner et al. 2012). Figure 1 shows energy efficiency's effect on energy service demand.

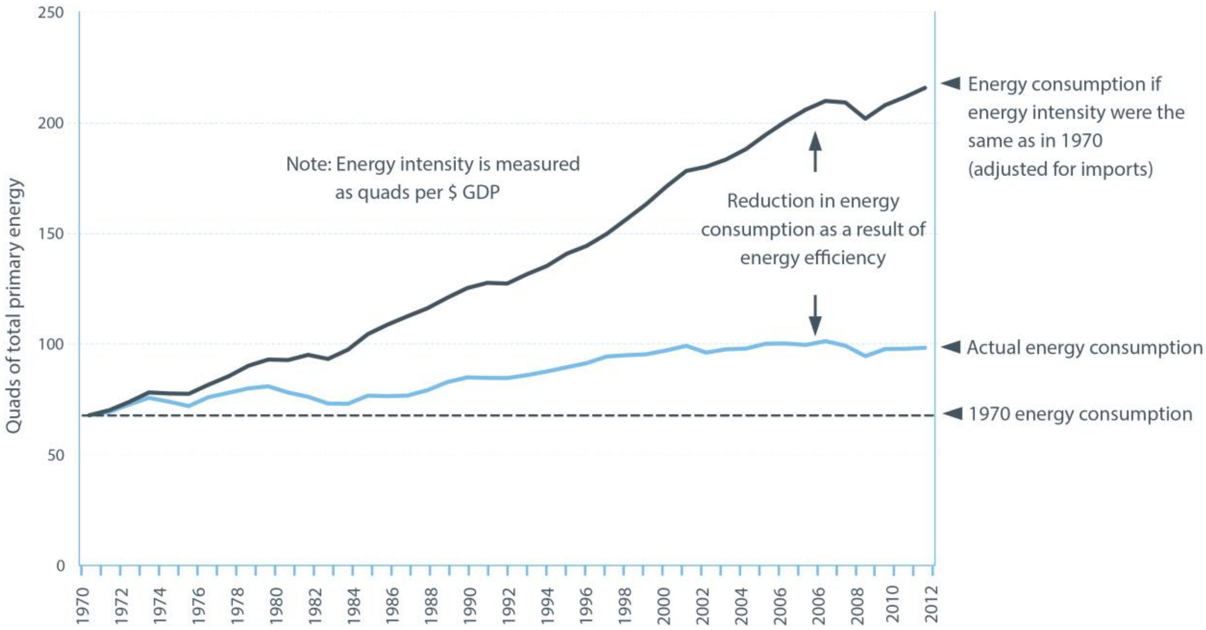

Figure 1. Effect of energy efficiency on total demand over time. *Source:* Updated from Laitner et al. 2012.

EPA should set a robust emissions standard in light of the efficacy of energy efficiency. Not only will such a standard help states achieve significant emissions reductions, it will also enable them to reduce consumer costs.

It costs significantly less to reduce carbon emissions through energy efficiency than through other means. For one thing, energy efficiency can meet electricity demand at less cost than it takes to generate power from fossil-fuel power plants. Figure 2 illustrates the cost to utilities of meeting electricity demand through efficiency as compared to meeting it by constructing and operating new generation.

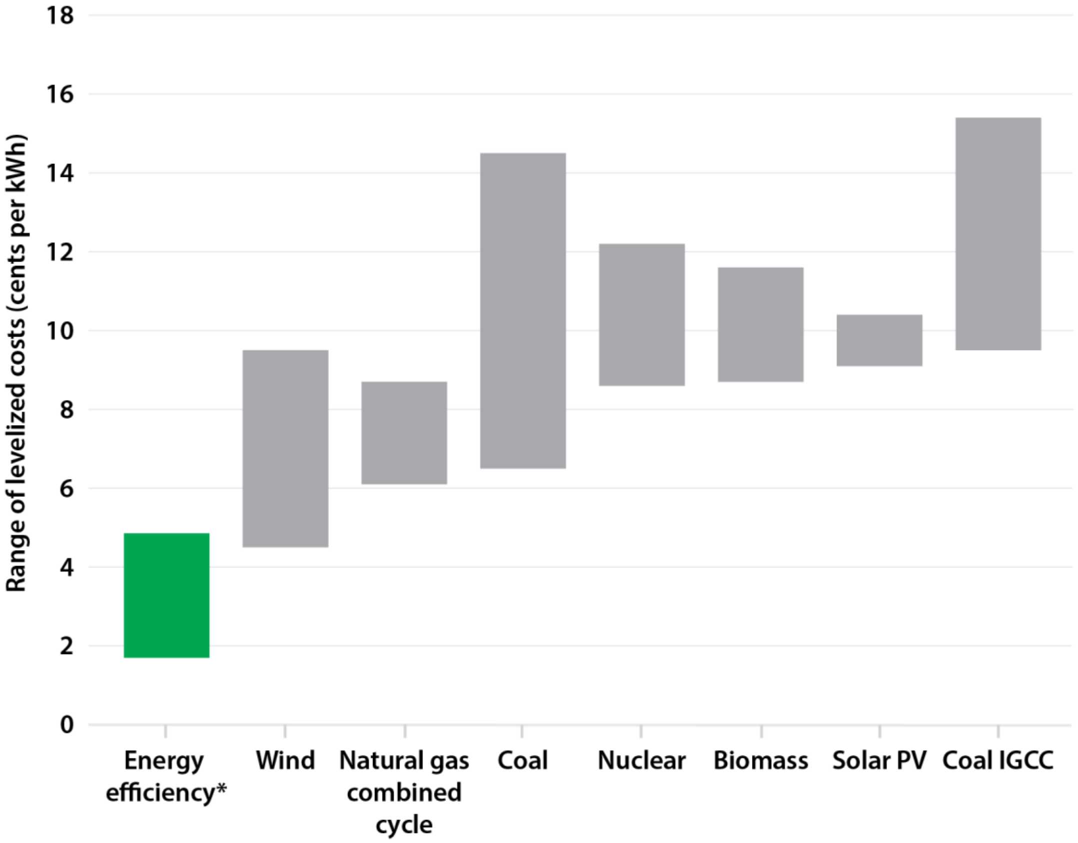

Figure 2. Levelized cost of various energy resources. High-end range of advanced pulverized coal includes 90% carbon capture and compression. *Source:* Molina 2014.

The lower cost of end-use energy efficiency creates a two-for-the-price-of-one deal: states that implement efficiency get electricity services at a lower cost than they would with other options while they reduce pollution at no additional cost. Not only is end-use efficiency the lowest-cost resource option for electric utilities, it can also reduce the cost of delivering electricity—including the need to build new capacity and maintain and upgrade the transmission and distribution system—while promoting grid resilience and reliability (Lazar and Colburn 2013).

There are additional advantages to including end-use energy efficiency as a compliance mechanism in a Section 111(d) rulemaking. Efficiency decreases fuel price volatility and improves energy security. By lowering emissions, it reduces the cost to states of meeting particulate matter and ozone regulations. It also minimizes public health damage due to mercury, acid gas, and other forms of air pollution.[6]

The great majority of states already implement at least some end-use energy efficiency policies and programs, and the untapped opportunities that remain are substantial. Rather

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[6] For more information on the multiple benefits of end-use energy efficiency see Lazar and Colburn 2013.

than imposing an entirely new set of administrative requirements, EPA should recommend a system for emission reductions that builds on what states have already done to develop, implement, and administer their efficiency resources.

ASSESSING THE OPPORTUNITY

Under Section 111(d), states are ultimately responsible for developing and implementing the plans that will reduce their emissions. For the purposes of this analysis, we chose four of the most common and effective energy efficiency policies a state could adopt:

- An energy savings target
- More stringent building energy codes
- New investment in combined heat and power (CHP)
- Equipment energy efficiency standards

We use actual state experience and conservative assumptions to estimate the impacts those policies would have on electricity consumption, jobs, the economy, and the environment. We describe our approach in the Methodology section and provide additional detail in Appendices A and B. The Results and Discussion section highlights the major findings of our analysis, with additional findings included in Appendix C. Finally, we summarize results for three representative states: Missouri, Ohio, and Virginia. Results for other states can be found in Appendix C.

Methodology

Our analysis estimates the electricity savings and economic impacts that states could achieve by implementing a particular state-level energy efficiency policy. The policies we analyze are:

- Implement an energy efficiency savings target of 1.5% per year
- Adopt and implement national model building codes
- Construct combined heat and power (CHP)
- Adopt energy efficiency standards for five products[7]

We analyze the energy efficiency potential in a scenario in which states adopt these four policies and use established practices and technologies to implement them. Each of the policies is assumed to operate independently (i.e., state energy savings targets do not include CHP or building codes). We rely on actual state experience to estimate the impacts the policies would have on electricity consumption, the environment, the economy, and jobs. Our analysis is intended to be moderate. It relies on conservative assumptions and

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[7] Some of these policies also reduce direct consumption of natural gas, fuel oil, propane, and wood. For example, a building that is heated by a gas-fired furnace will use less gas when insulated. We did not include these additional energy benefits in our calculation of electricity savings or cost savings. However, to the extent that the efficiency scenario we analyzed would impact natural gas consumption, we modeled the changes in income at gas utilities and in household and business expenditure in our calculations of job and GDP impacts.

common current practices, and the results represent policy targets that each state can reasonably achieve. For example:

- *Annual energy savings target*. Several states have achieved or set the goal of an energy efficiency savings target of 2% new savings each year compared to the previous year's electricity sales. In our scenario, all states are assumed to achieve savings that ramp up to 1.5% annually, in spite of the fact that higher savings could be cost effectively achieved.
- *Building energy codes*. In our building codes scenario, we report only electric savings that would be achieved in new buildings. In reality, building codes result in energy savings for other fuels such as natural gas and fuel oil, and they also often apply to the renovation of existing buildings.
- *Combined heat and power*. We report a subset of the economic potential of CHP. This is a conservative approach in that we assume no additional financial incentives.
- *Equipment efficiency standards*. We estimate savings from only five products.[8] This analysis is conservative because some states are currently regulating many more products.

Most states have already implemented energy efficiency policies of some kind, and some have already adopted most of the policies analyzed in this paper. Eleven states already have annual electricity savings targets in place of 1.5% or greater. Several have adopted the latest model building energy codes, and some have already set standards for the equipment included in our scenario.

Efficiency savings are typically measured according to a predetermined life cycle. For example, the installation of efficient lighting will probably not accrue savings for as long a period as upgrades to a building envelope. Once an efficiency investment has been made, it accrues savings for each year of its life cycle. We consider efficiency measures already installed as part of the baseline or starting place for states. We do not include baseline measures in our savings estimates. However, for measures not yet installed, we treat their benefits as new benefits.

For example, if a state has adopted a savings target that requires savings of 1.5% per year and has successfully achieved those savings for the last three years, we count the savings occurring from the last three years as "baseline." However, any savings achieved as part of the 1.5% target in future years are "new." We make this assumption because, although the policy is already in place, the state has not yet made the investment required to implement the policy in future years, and it could change its policy or fail to achieve its goal.

For building energy codes, we calculated the savings that would be achieved from the adoption of the newest model codes relative to an estimate of the energy intensity of

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[8] The five products are double-ended quartz halogen lamps, residential lavatory faucets, commercial hot-food holding cabinets, portable electric spas, and bottle-type water dispensers.

existing buildings (which varies depending on the code already in place in each state).[9] For CHP and equipment standards, we estimated the likely construction and market penetration, respectively, of these policies to determine energy savings in each state.

For several of the measures, we assumed that some type of financing mechanism paid for some or all of the incremental costs of the energy-saving measures. For building energy codes, for example, we assumed that consumers paid for the increased costs associated with building a more efficient home by adding those costs to the mortgages used to finance the rest of the home. For each measure subject to this assumption, we used interest rates appropriate to the type of loan, and we used projections published by U.S. Energy Information Administration (EIA) in the *Annual Energy Outlook 2013* (AEO) Reference Case in order to project changes in those rates over time.[10]

Each of the four scenarios we analyzed is described briefly below. These descriptions are followed by an overview of our approach to calculating the impacts of these policies on employment and the economy. Detailed assumptions for all our calculations can be found in Appendices A and B.

ENERGY EFFICIENCY SAVINGS TARGET

One of the most common and effective ways for states to take advantage of energy efficiency resources is to set a target to achieve a certain amount of energy savings. This goal can come from the adoption of legislation or through regulation, and it can be set for a statewide program administrator or for specific utility or third-party program administrators. Currently, 25 states have adopted an energy efficiency resource standard (EERS).[11] Figure 3 below shows which states have adopted an EERS.[12]

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[9] We used the energy intensity of existing buildings constructed after 2000 as the comparison point for the energy intensity of buildings constructed to current code, partly because state-specific data on the energy intensity of new buildings was unavailable. On average we found that the energy intensity of existing residential and commercial buildings constructed after 2000 was comparable to the energy intensity of buildings constructed at ASHRAE 90.1-2004 and 2003 IECC respectively.

[10] We also used regional energy price and energy consumption projections published by EIA in the AEO 2013 Reference Case combined with state-level data mostly from EIA.

[11] ACEEE defines an energy efficiency resource standard as a long-term (3+ years), binding energy savings target for utilities or non-utility program administrators that has a dedicated funding source.

[12] More information on the annual savings goals required in those states can be found in the ACEEE *2013 State Energy Efficiency Scorecard* (Downs et. al 2013) and our state energy efficiency policy database (http://www.aceee.org/sector/state-policy).

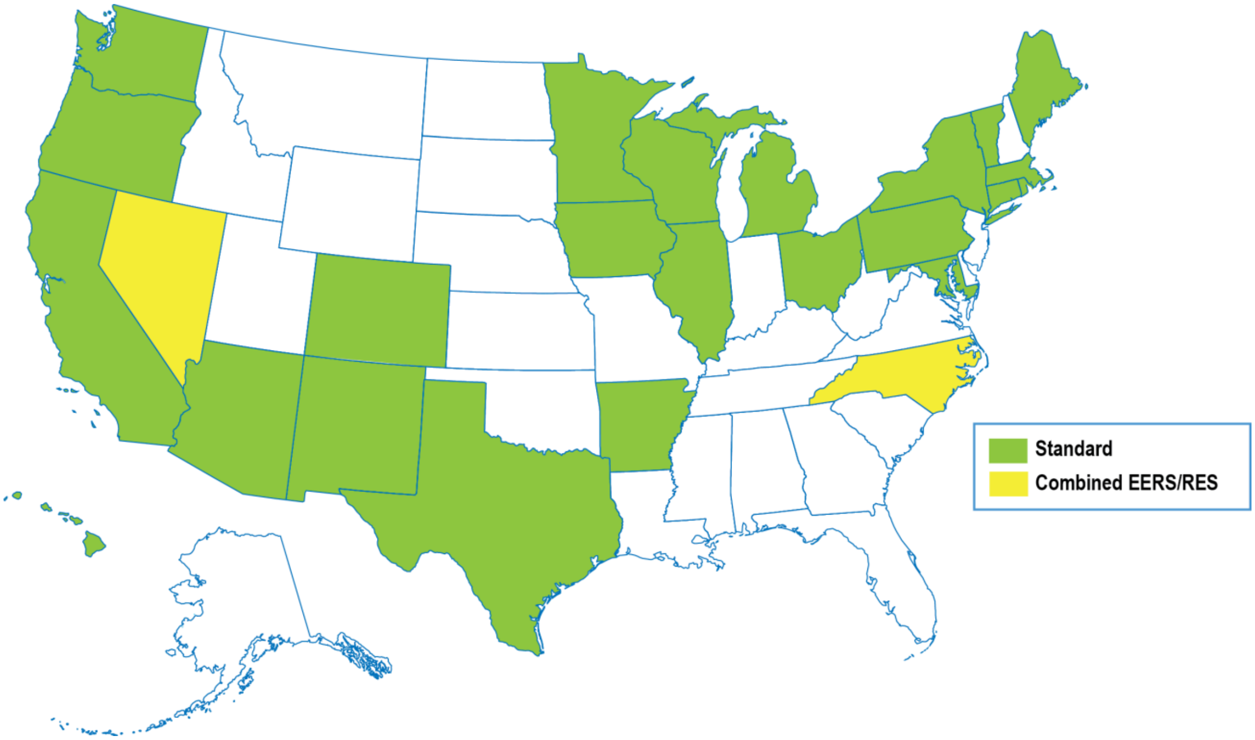

Figure 3. States with an EERS policy. Some states combine energy efficiency savings with a renewable energy standard (RES). *Source:* ACEEE 2014.

In this analysis, we assume that each state adopts a savings target that ramps up to 1.5% of electricity sales per year. This means that each year the state will achieve new savings equal to 1.5% of the previous year's electricity sales. Since it can take time to design, approve, and implement efficiency programs, our analysis assumes that efficiency savings ramp up gradually. Policies are assumed to begin in 2016, and their energy savings are projected through 2030. The 2016 starting point is actual statewide 2011 or 2012 (as available) electricity savings levels.[13] Cost estimates are based on actual spending data for 18 states.[14]

As shown in table 1, five states now have incremental savings targets of 2% or more of sales per year, and six others states have targets of 1.5% or more of sales per year.

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[13] If 2011 savings levels are below 0.25%, we assume the state begins at 0.25% in 2016. If a state is currently achieving less than 1.5%, we assume the state begins at its current savings level and ramps up by 0.25% per year until 1.5% is achieved; 1.5% then remains the constant annual savings through 2030. For example, a state that is currently achieving 1% savings per year would achieve 1.00% in 2016, 1.25% in 2017, and 1.5% in 2018 and each year thereafter through 2030. If a state is currently achieving or plans to achieve savings higher than 1.5%, those savings would be additional to our model.

[14] The data used to develop cost estimates are available in Molina 2014.

Table 1. State savings targets

Approximate annual savings target in 2013	Number of states	States
2% or greater	5	Massachusetts, Arizona, Rhode Island, New York, Vermont
1.5% - 1.99%	6	Illinois, Maryland, Maine, Minnesota, Colorado, Indiana
1.0% - 1.49%	9	Connecticut, Iowa, Oregon, Washington, Hawaii, Ohio, New Mexico, Michigan
0.5% - 0.99%	4	California, Wisconsin, Pennsylvania, North Carolina, Arkansas

Nevada has a savings target of 0.2% and Texas has a target of 0.1%. Indiana legislators recently voted to end the efficiency programs associated with the state's EERS; that decision was made after research for the report was completed. *Source:* http://www.aceee.org/sites/default/files/publications/researchreports/e13k.pdf

BUILDING ENERGY CODES

Building codes establish minimum requirements for the design and construction of new and renovated residential and commercial buildings. States have the authority to adopt building codes, which are generally based on model codes developed by national consensus standards organizations. The International Code Council develops the International Energy Conservation Code (IECC)—the national residential model code—and updates it every three years. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) updates model commercial codes (ASHRAE Standard 90.1) every three years. The most recent national model codes date from 2012 and 2010 for residential and commercial buildings respectively.[15] While many states have been leaders, not all states have adopted model building codes, and almost all of them are several years behind in adopting the most recent codes. Figures 4 and 5 below show the current status of building code adoption by state.

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[15] The 2013 standard has recently been developed for commercial buildings; however we used the 2010 standard here because the data needed to complete our analysis are not yet available for the new standard.

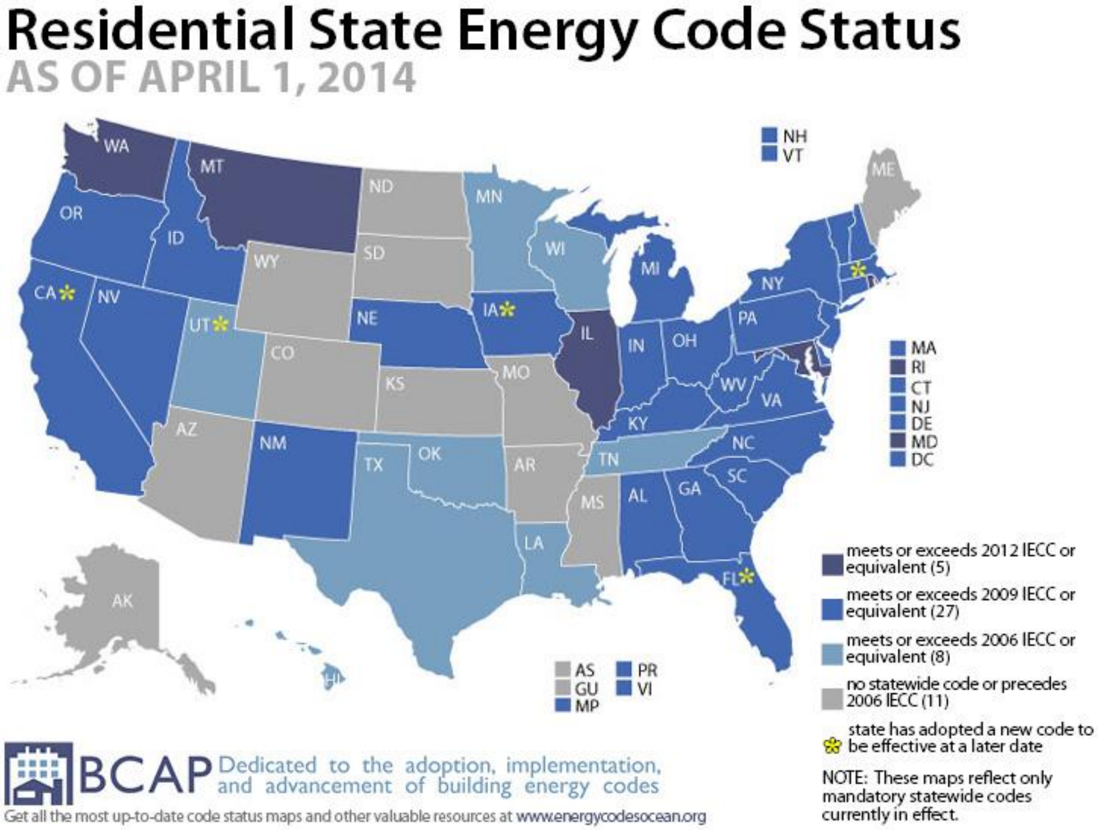

Figure 4. Residential state energy code status. *Source:* Building Code Assistance Project (BCAP), http://bcap-energy.org/

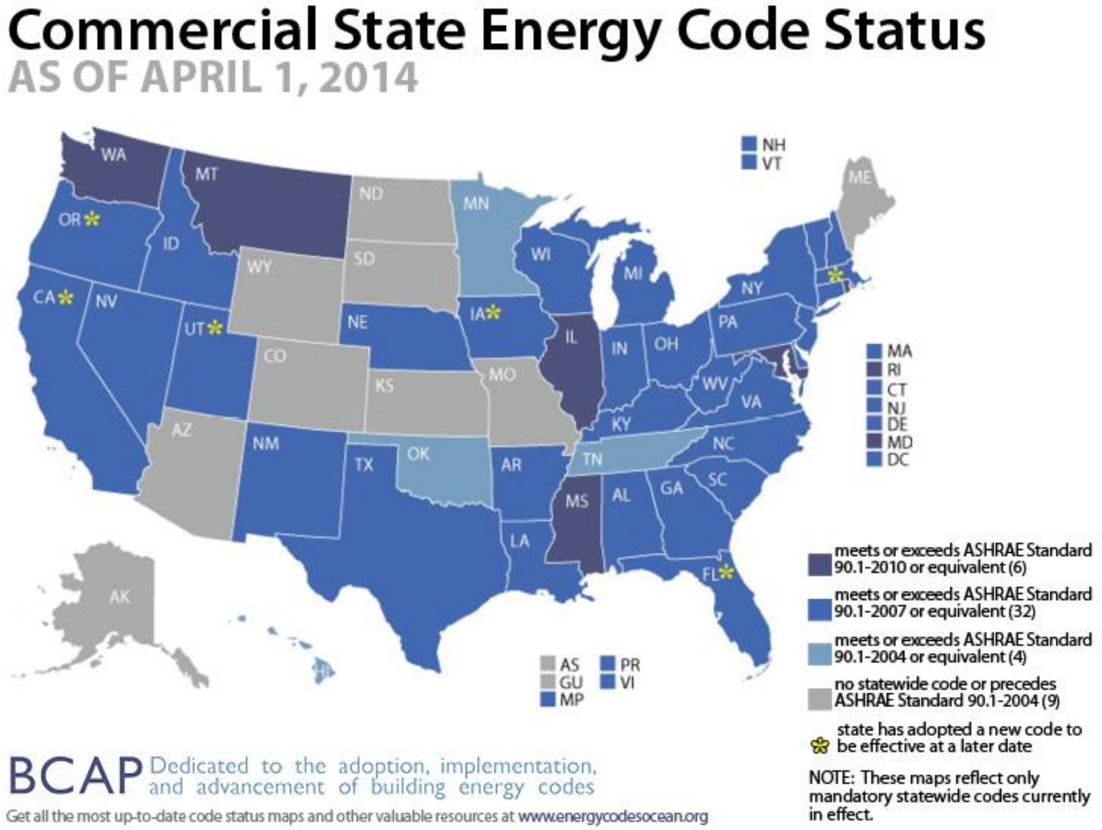

Figure 5. Commercial state energy code status. *Source:* Building Code Assistance Project (BCAP), http://bcap-energy.org/

In this analysis, we model a scenario for residential buildings in which by 2016 all states have adopted the 2012 IECC model code (in effect from 2016 to 2021). In 2022 all states adopt the 2021 IECC model code, which is in effect for the remainder of our analysis. For commercial buildings, we model a scenario in which by 2016 all states have adopted the ASHRAE Standard 90.1-2010, which is in effect from 2016 to 2019. In 2020 all states adopt the 2016 standard, which is in effect for the remainder of our analysis. Both the 2021 IECC and ASHRAE Standard 90.1-2016 are assumed to reach 50% energy savings, meaning energy consumption is assumed to be 50% of what it would otherwise be under the 2006 IECC and 90.1-2004 respectively.[16]

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[16] These savings levels are consistent with the goals and savings levels adopted by ASHRAE in their 90.1 standard and 90.2 workplan.

While building codes save both natural gas and electricity, the energy savings numbers we report only include electricity savings.[17] Due to data limitations, we estimate the energy savings and costs that would accrue only for new buildings, not for renovated buildings.

COMBINED HEAT AND POWER

CHP is the concurrent generation of electric power and useful thermal energy. CHP is not a single technology, but a particular application of a suite of technologies including engines and turbines. Natural gas, coal, biomass, biofuels, and other resources fuel CHP units. Given the concurrent generation of power and useful thermal energy, the overall combined electric and thermal efficiency of CHP units can reach or exceed 80%, whereas the current electric generation fleet is only about 35% efficient.[18] CHP conveys such substantial efficiency benefits because it does more with a single fuel input than does typical electric generation, mostly through capture of waste heat. CHP technologies are also usually located near the point of consumption, so the losses associated with long-distance transmission and distribution are reduced.

CHP currently represents about 8% of installed U.S. electric generating capacity. Recent additions of CHP capacity have been concentrated in just a few states, including New York, California, Texas, and Connecticut.

For purposes of this analysis we assume the following scenario for each state:

- Both commercial and industrial CHP investments increase due to the adoption of state policies that value and encourage CHP (such as a specific CHP goal).
- No additional revenue streams (e.g., net metering or feed-in tariffs) are in place for CHP.
- CHP is deployed only where cost effective. Most new facilities will have short payback periods.
- New CHP is fueled by natural gas, which is currently the predominant fuel used by U.S. CHP systems.[19]
- CHP systems do not export excess power to the grid.

This analysis represents a conservative estimate of the potential for CHP; additional policies could result in a higher level of implementation. See Appendix B for more detail on the CHP scenario.

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[17] To the extent that building codes reduce consumption of natural gas, our economic analysis includes the impact of both the reduced expenditures on natural gas and reduced revenues to natural gas utilities (and their suppliers).

[18] New combined cycle gas turbine power plants can achieve efficiencies of >60%.

[19] To the extent that increased deployment increases the consumption of natural gas, our economic analysis includes the impact of increased expenditures on natural gas by consumers and increased revenues to natural gas utilities (and their suppliers).

EQUIPMENT EFFICIENCY STANDARDS

Equipment efficiency standards set minimum energy efficiency levels for new appliances, equipment, and lighting. After a state-level standard takes effect for a given product, models that do not meet the minimum efficiency level can no longer be sold or installed. Thus efficiency standards set a floor for the efficiency of the affected products.

More than 50 products are currently subject to federal appliance efficiency standards. However many energy-consuming products are not, including some products with significant annual electricity consumption such as computers and game consoles. States cannot set efficiency standards for federally regulated products, but they can set standards for other products.

In fact, states have often taken the lead in establishing efficiency standards. Most of the products now covered by national standards were first subject to state standards. For example, California, New York, and Florida established standards for refrigerators in the 1970s and 80s that were a catalyst for and the basis of the national refrigerator standards established in 1987.

State standards are set by legislatures or state agencies. In New York, for example, the state legislature has directed the New York Department of State to develop standards in consultation with the New York State Energy Research and Development Authority (NYSERDA). In California, the California Energy Commission (CEC) develops and adopts new standards. Since 2001, Arizona, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Washington have each passed state standards.

In this analysis we analyzed potential state standards only for products already subject to a standard in at least one state. (It should be noted that California is currently considering energy efficiency standards for an additional nine products including computers, game consoles, fluorescent dimming ballasts, and commercial clothes dryers.) Our estimates of the potential electricity savings from state standards are conservative, since states might adopt standards for additional products beyond those we have analyzed.

For this analysis, we assume the following energy efficiency scenario for equipment:

- Each state adopts standards for five products: double-ended quartz halogen lamps, residential lavatory faucets, commercial hot-food holding cabinets, portable electric spas, and bottle-type water dispensers.
- Each of the five standards takes effect in 2016. Beginning in 2016, all sales of the five products in the state meet the minimum efficiency level.
- Over time, the electricity savings from the standards increase as more of the stock of the affected products turns over and is replaced by more efficient models that meet the new standards.

POLLUTION IMPACTS

We did not directly calculate the impact of our policy scenarios on pollution. Instead, we relied on established tools and methods to estimate the likely pollution reduction. We used three approaches, each of which has shortcomings. All three approaches yielded similar results; we report the average. The approaches are described below.

EPA's recently published AVoided Emissions and geneRation Tool (AVERT) represents the dynamics of electricity dispatch based on the historical patterns of actual generation in one selected year (EPA 2014). AVERT's main module estimates the displaced emissions likely to result from efficiency programs in reference to a base-year scenario.

AVERT analyzes how hourly changes in demand in a user-selected historical base year modify the output of fossil-fired electric generating units. Using detailed hourly data from EPA's Air Market Program Data, AVERT probabilistically estimates the operation and output of each electric generating unit in a given region based on that region's hourly demand for fossil-fired generation. This information is used to predict electric generating units' likely operation in response to load impacts from efficiency or renewable resources.

We entered results for the lower 48 states across the 10 AVERT regions and then summed them to create a national estimate of avoided emissions. EPA's instructions for AVERT specify that the tool should not be used for forecasts beyond five years. We acknowledge the limitations of this tool and the fact that the resource mix of electric power generation is likely to shift in coming years. Therefore the estimates of pollution impacts we include are intended to provide an order-of-magnitude estimate only.

Our second method relies on the EPA Power-Plant Emissions Calculator (P-PEC). P-PEC is a spreadsheet-based tool that estimates electric-power-sector emission reductions of nitrogen oxides (NO_x), sulfur dioxide (SO_2), and carbon dioxide (CO_2) from energy efficiency policies or programs that can reduce electricity demand. P-PEC does its calculations based on data from the EPA Emissions and Generation Resource Integrated Database (eGRID), which contains detailed information on capacity factors, location, generation, and emissions for almost all the power plants in the lower 48 states. P-PEC uses data from 2009 and relies on a capacity factor approach.[20] This tool has some of the same limitations as AVERT, which mean the results we report are order-of-magnitude estimates only.

Our third method of estimating pollution impacts uses a percentage reduction in electricity consumption from a baseline to determine a corresponding percentage reduction in CO_2 emissions. Using data for the lower 48 states published in the EIA 2014 AEO (early release), we calculated an overall percent reduction in electricity consumption by dividing our results of avoided electricity consumption for 2020 and 2030 by the corresponding projections of annual electricity consumption in AEO 2014. We then calculated the tons of CO_2 emissions that would be avoided in 2030 if reduced by an equivalent percentage.

A major shortcoming of this method is that AEO projections already include some energy efficiency. Our energy savings estimates are total savings from a baseline year and are not relative to AEO forecasts; they are additional to savings already included in AEO.

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[20] For a description of the capacity factor rule of thumb, see page 3 of the Power Plant Emissions Calculator (P-PEC) Draft User Manual (EPA 2012).

MACROECONOMIC AND EMPLOYMENT IMPACTS

Energy efficiency is a low-cost resource for meeting energy demand. Energy supply requires investment in power plants and grid infrastructure, state government oversight, and consumer expenditures for energy. Improving energy efficiency can lower the costs of energy supply and reduce consumer spending on energy. At the same time, it increases utility and state government expenditures for efficiency programs and regulations.

Investments in efficiency result in economic benefits because they save consumers money which is then redirected into other sectors of the economy. This shift in spending creates jobs. The jobs estimates we report are for net jobs, meaning that they include any job losses that may occur as money is redirected from one sector to another.

Our economic modeling is based on standard input-output methodology, tracking expenditures and savings across the entire economy divided into 14 different producing industries and households (see Appendix A). The analysis passes our energy savings and investment results into our economic model, calculating the net impact on final demand for goods and services. The net changes in final demand enter the input-output matrix and determine the ultimate impact on employment, income, and other variables.

Expenditures on efficiency investments by the three broad sectors (commercial, industrial, and households) are treated as a stimulus to the economy, flowing into construction, manufacturing, and service industries. At the same time, these investments must be paid for. Efficiency programs run by electric utilities, for example, are paid for through increased electricity rates incurred by the relevant sector. Expenditures for energy efficiency (including interest payments for investments that are financed) reduce the amount of money available to be spent on other goods and services. We account for this by reducing expenditures by the commercial, industrial, and household sectors on other goods and services based on their current expenditure patterns. Finally, energy savings are returned to the three sectors, and they are assumed to spend this money according to those same patterns.

The input-output model associates these net spending changes with the appropriate industries and generates projections for employment and other variables. The projections are based on industry- and state-specific parameters for labor and other input requirements for each industry.

Results and Discussion

Our analysis demonstrates that a state will accrue considerable benefits if it adopts the four energy efficiency policies in our scenario. In 2030, these policies would avoid 600 million tons of carbon dioxide emissions and save 925 million MWh of electricity. They would also avoid the need for 494 power plants.[21]

What would adopting these policies cost? It would cost less than business as usual and much less than the cost of meeting demand and separately reducing pollutants. This is because the energy savings from these cost-effective policies can meet energy demand while producing no pollution. Energy efficiency is a low-cost answer to several challenges. It maintains reliability as old power plants retire, meets demand without the expense of building new power plants, and avoids expensive emission control technologies that would needed to keep older, inefficient power plants operating.

Our policy scenario is also good for the economy: not only does it reduce waste, but it creates 611,000 American jobs. Implementing these policies would increase national gross domestic product by $17.2 billion in 2030.

The following discussion presents the high-level results of our analysis and explains what these findings mean for greenhouse gas regulations. The discussion concludes with a snapshot of how adoption of the policies in our scenario would benefit three states: Missouri, Ohio, and Virginia.

NATIONAL BENEFITS

Our scenario produces an array of benefits due to the potential of energy efficiency to address multiple challenges at once. For example, in the case of an energy-savings target, utilities may offer their customers rebates to lower the cost of high-efficiency equipment (e.g., a clothes washer or refrigerator that is more efficient than the cheaper base models available on the market). Once the equipment is installed, energy demand is reduced from what it otherwise would have been. This reduction in demand means less electricity needs to be generated to meet consumers' needs, which in turn reduces pollution as well as utilities' need to invest in transmission and distribution grids. Reducing electricity demand from power plants also gives states flexibility. They can avoid constructing new power plants and can retire outdated ones, obviating the cost of retrofitting them with air and water pollution controls.

Replacing electricity consumption with energy efficiency can also save consumers and businesses money. Building new fossil-fuel-fired power plants to meet demand would cost two to three times what it would cost to meet that demand with energy efficiency. Meeting energy needs with efficiency instead of generation also reduces pollution and produces numerous additional benefits.[22] The key benefits of our efficiency scenario include the following:

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[21] Estimate based on 500 MW power plant. Assumes 5% line loses and the national average capacity factor of 45%.

[22] For discussion of additional benefits see Lazar and Colburn (2013).

- CO_2 pollution avoided in a single year (2030): 600 million tons
- Additional jobs in 2030: 611,000
- Annual electricity savings: 925 million MWh
- Cumulative electricity savings: 7,247 million MWh

Figure 6 compares some of the benefits and costs of a future with energy efficiency policies and one without.

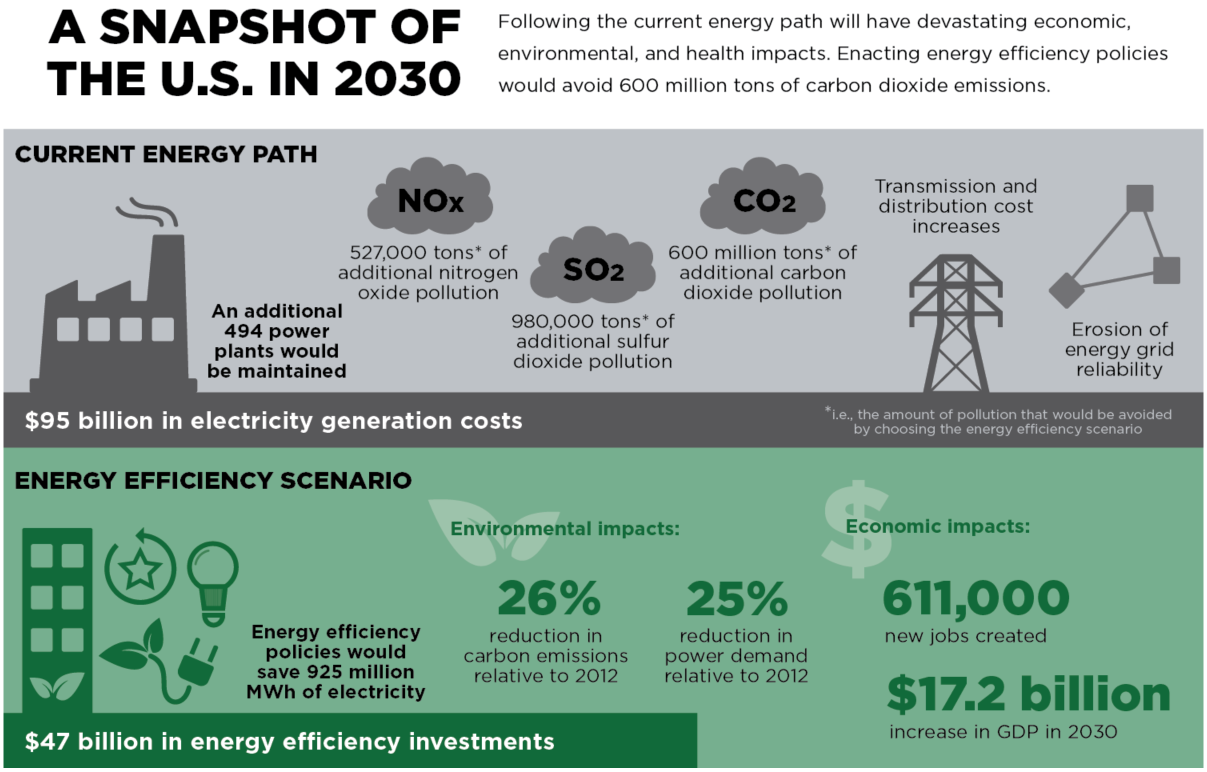

Figure 6. Current U.S. energy path versus energy efficiency scenario

ELECTRICITY SAVINGS

The cumulative electricity savings from all four policies combined is over 7 billion MWh by 2030. In that single year, savings would be over 925 million MWh. Projected electricity consumption is reduced by 25% in 2030 relative to 2012. This reduction would obviate the need for approximately 494 power plants in 2030.[23]

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[23] Estimate based on 500 MW power plant. Assumes 5% line loses and a 45% capacity factor.

Of the four individual policies, the energy savings target yields the most electricity savings: over 690 million MWh in 2030, which is 75% of the total savings achievable under our four-policy scenario.

The building energy codes policy achieves 17% of the total electricity savings in our scenario. This amount is conservative, given that it represents electricity benefits to new buildings only. In fact building codes will create additional savings due to (1) reduced natural gas consumption and (2) improvements to existing buildings. Neither of these benefits is included in our total.[24]

Policies to encourage CHP yield an achievable potential of about 20 GW by 2030, which is 7% of our total savings. This represents only a subset of the economic potential for CHP since we screened each CHP investment using state- and sector-specific forecasted electricity and natural-gas prices to ensure that only cost-effective CHP with shorter-term paybacks was installed.

The equipment standards policies are responsible for the remaining 1% of total electricity savings in our scenario. It should be noted that the savings here are limited to standards for just five products, even though states could adopt standards for many more.

The tables below list the total electricity savings that would be realized if every state adopted our energy efficiency scenario. The tables demonstrate that every state could meet a substantial portion of its electricity needs by tapping into its energy efficiency resource.

Table 2. 2020 electricity savings if all four policies adopted

Policy	Annual electricity savings (MWh)	Cumulative electricity savings (MWh)	Avoided capacity (GW)
Energy savings target	202,800,000	537,300,000	54
Building codes	34,700,000	92,700,000	9
Combined heat and power	23,300,000	64,900,000	6
Equipment standards	6,700,000	24,600,000	2
National total for all four policies	267,500,000	719,500,000	71

Annual electricity savings are electricity savings occurring in a single year from the combination of program measures implemented in the current year and active savings from measures implemented in prior years. These savings are the sum of all incremental annual savings up to the year being calculated, less expired savings from previous years after the end of the measure life. Cumulative electricity savings represent the sum of the annual electricity savings over a multi-year time frame. Avoided capacity is calculated by applying the national average capacity factor of 45% and assumes 5% line losses.

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[24] As noted above, the economic impacts of reduced natural gas demand are included in the economic analysis.

Table 3. 2030 electricity savings if all four policies adopted

	Annual electricity savings (MWh)	Cumulative electricity savings (MWh)	Avoided capacity (GW)	Percent avoided electricity consumption relative to 2012
Energy savings target	692,200,000	5,470,500,000	185	18.8%
Building codes	155,400,000	1,100,100,000	41	4.2%
Combined heat and power	68,300,000	564,500,000	18	1.9%
Equipment standards	9,400,000	112,100,000	3	0.3%
National total for all four policies	925,400,000	7,247,200,000	247	25.1%

Table 4. Percentage of electricity savings relative to 2012 consumption, by state

State	Total (all four policies)
National	25%
Alabama	22%
Alaska	35%
Arizona	39%
Arkansas	22%
California	28%
Colorado	28%
Connecticut	30%
Delaware	23%
District of Columbia	26%
Florida	25%
Georgia	24%
Hawaii	36%
Idaho	23%
Illinois	23%
Indiana	22%
Iowa	25%
Kansas	23%
Kentucky	22%
Louisiana	26%
Maine	26%
Maryland	23%
Massachusetts	32%
Michigan	21%
Minnesota	24%
Mississippi	24%

State	Total (all four policies)
Missouri	21%
Montana	23%
Nebraska	19%
Nevada	24%
New Hampshire	31%
New Jersey	27%
New Mexico	30%
New York	37%
North Carolina	24%
North Dakota	21%
Ohio	23%
Oklahoma	22%
Oregon	27%
Pennsylvania	23%
Rhode Island	25%
South Carolina	24%
South Dakota	20%
Tennessee	26%
Texas	25%
Utah	27%
Vermont	28%
Virginia	23%
Washington	23%
West Virginia	23%
Wisconsin	24%
Wyoming	25%

Table 5. Percentage of electricity savings relative to 2012 consumption, by census region

Region	Total (all four policies)
New England	30%
Middle Atlantic	28%
South Atlantic	24%
East South Central	23%
West South Central	24%
East North Central	22%
West North Central	22%
Mountain	30%
Pacific	27%

The full results of our analysis by policy and state are available in Appendix C.

POLLUTION

As discussed in the Methodology section, we used three different methods to estimate pollution impacts. We found that in total our policy scenario would eliminate approximately 177 million tons of carbon dioxide in 2020 and 600 million tons in 2030. The 2030 quantities represent a 26% reduction relative to 2012 power-sector emissions.

Our results show that a regulation implementing meaningful limits on greenhouse gas emissions from existing power plants can be achieved with energy efficiency alone. Applying a combination of additional control strategies (e.g., load shifting, power-plant efficiency upgrades, renewable energy) could reduce emissions even further. Table 6 compares the avoided CO_2 results for each of the three methods we used to estimate pollution impacts.

Table 6. Avoided CO_2 (million tons)

Method	2020	2030
AVERT	180	680
P-PEC	170	590
Percentage method	180	530
Average	180	600

In addition to reducing greenhouse gas, meeting demand with end-use efficiency eliminates mercury, particulates, smog, and a long list of additional hazardous air pollutants. Table 7 below lists some of the pollution that would be avoided with the adoption of the four policies in our scenario. [25]

Table 7. National pollution benefits of ACEEE scenario (tons)

	2020	2030
SO_2	263,000	980,000
NO_x	149,000	527,000

Hazardous air pollutants cause thousands of hospital visits and premature deaths every year (National Research Council 2010). By reducing them, our scenario would avoid over 147,000 asthma attacks in 2030 and over 5,000 premature deaths.[26] Pollution results in lost productivity as well. Our policy scenario would avoid losses of almost $100 million due to lost work days.[27]

ECONOMIC IMPACTS

End-use energy efficiency simultaneously offers multiple benefits including the following:

- Meets electricity needs
- Reduces pollution
- Reduces congestion and line losses on the grid
- Reduces stress on transmission lines
- Improves living conditions
- Reduces premature deaths and illnesses of sensitive populations including children and the elderly

In each of these areas, energy efficiency saves money and is usually the least expensive option compared to other generation resources. For example, the pollution benefits from energy efficiency cost nothing; they are essentially free. In terms of meeting electricity needs, our policy scenario saves over 925,000 MWh in 2030. The cost to generate those savings would be about $47 billion (2011$).[28] If the United States were to meet that same demand by generating electricity, it would cost nearly $95 billion. Thus the efficiency

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[25] Annual avoided electricity consumption was used to model reductions in NO_x, and SO_2 using EPA's AVoided Emissions and geneRation Tool (AVERT).

[26] Calculated using EPA's COBRA tool (EPA 2013): http://epa.gov/statelocalclimate/documents/pdf/cobra-2.61-user-manual-july-2013.pdf.

[27] For additional discussion of the health risks associated with air pollution and the corresponding economic impacts, see The Economist (2014).

[28] This is based on the undiscounted value of the investment required to generate a kWh's worth of savings over the entire forecast horizon. All dollar values are inflation adjusted to 2011.

scenario saves $48 billion. Without efficiency, states would end up spending more to generate electricity and lose out on all the other benefits listed above. It is true that implementing our policy scenario will require investments. However by avoiding the need to generate electricity, those investments will save more than what they cost. As shown in table 8, the range of savings to cost ratios in all states and for each of the four policy areas is 1.0 or greater.[29]

Table 8. Savings relative to costs of energy efficiency policies

	High and low range for all states
Energy savings target	1.1 - 4.9
Building codes	1.8 - 3.0
CHP	1.0 - 4.1
Equipment standards	1.8 - 9.4

Not only does it cost less to meet electricity needs through increased efficiency than through generation, but shifting from expenditures on generation to investment in efficiency also creates more jobs and more rapid economic growth. For example, investments in home energy retrofits or more efficient equipment shift money away from the purchase of coal, oil, and gas (money that sometimes finds its way to pockets in foreign economies). Instead, this money is used to pay local contractors and builders, or to retool American factories and manufacturing facilities to produce more efficient products. Our analysis finds that shifting these investments has a positive impact on the gross state product (GSP) of almost every state.[30] State-by-state GSP impacts of our policy scenario can be found in Appendix C.

JOBS

If the four energy efficiency policies were adopted, there would be over 611,000 more people employed in 2030 than there would be in the absence of the policies. Over the 15 years from 2016 through 2030, the efficiency investments would add nearly 6.2 million new job-years to the economy.[31]

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[29] For the purposes of this analysis, benefits from the four policies included only avoided retail costs of energy based on sector. Many ancillary benefits occur as a result of energy efficiency which have positive financial effects, such as reduced pollution and improved health. The financial impacts of these benefits were not included in benefit calculations.

[30] In seven states, the impact on gross state product was negligible, and in one state, West Virginia, the impact was slightly negative, despite the fact that the policies increase employment. This counterintuitive outcome is a result of a shift in expenditures towards more labor-intensive industries such as the service sector and away from those that contribute more toward GSP, like electricity. While all states experience this type of shift, West Virginia consumers spend nearly half their disposable income on imports from other states and foreign countries. Much of the economic value of the energy savings produced by efficiency policies leaves the state, yielding lower GSP.

[31] A job-year is one year's worth of full-time-equivalent employment. It could be one person working full time for a year or two people working full time for half a year, and so on.

The American Recovery and Reinvestment Act of 2009 (ARRA) provides a point of comparison. The Congressional Budget Office (CBO) estimates that in 2010 (the year when its estimated impact on jobs was greatest) ARRA lowered the unemployment rate by between 0.4 and 1.8%, and created between 900,000 and 4.7 million job-years.[32]

To look at the results of our analysis from another angle, the Bureau of Labor Statistics reports that in March 2014, there were a total of about 146 million employed people in the United States, of which 119 million were full time. About 10.5 million people were classified as unemployed, and the unemployment rate was 6.7% (BLS 2014c). If the roughly 611,000 jobs created in our scenario all accounted for new net job creation today, that would be enough to lower the unemployment rate to about 6.3%. Full results of our analysis by policy and state are available in Appendix C.

What these Findings Mean for EPA's Rulemaking

There has been a good deal of speculation about how a rulemaking should be structured, what it could achieve, and what the impacts of regulation might be on the economy. Our analysis provides some answers.

1. A CO_2 emissions standard set at 26% below 2012 levels can be achieved at no net cost to the economy. It will create 611,000 new jobs and have a positive economic impact on the country.

The policy scenario in our analysis would result in dramatic energy savings which would in turn reduce carbon dioxide by more than 26% compared to 2012 levels. These energy savings are so large that states would be able to avoid building expensive new power plants and could minimize investments to upgrade outdated, dirty generators. Implementing energy efficiency policies does involve costs, but those costs are significantly less than supplying an equivalent amount of electricity from a power plant. All the policies in our analysis have a benefit-cost ratio greater than 1, meaning that the energy benefits are greater than the investment required to implement the policies.

Not only are these policies good energy investments, but they will actually improve each state's overall economic outlook. The gross state product of most states improves with the adoption of these policies. National gross domestic product would increase by $17.2 billion in 2030.

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[32] As in the discussion below, this assumes that all the increased demand for labor results in new job creation. It is likely that at least some of that increased demand would result in workers being hired away from existing jobs with no net impact on employment levels. This effect is more pronounced in times of low unemployment, when there are fewer workers looking for jobs. We do not estimate the extent of this effect. It would be more technically accurate to say that the economy would support 611,000 more full-time job equivalents in 2030 than would otherwise have been the case.

The smart investments made under our scenarios strengthen the economy and create 611,000 jobs by 2030. While the jobs impact is larger in some states than others, every single state would see job creation.

It is also important to note that while end-use energy efficiency has long been cost effective, regulatory and market barriers continue to inhibit increased investments in efficiency policies and programs. A rulemaking that limits greenhouse gas emissions not only should recognize the emissions benefits of energy efficiency but also should be stringent enough to overcome existing market barriers. A rule that sets a weak standard or does not clear the path for efficiency would leave states with more expensive compliance options. As a result, the nation would lose out on the economic benefits we describe.

2. The U.S. power sector can significantly reduce greenhouse gases while states maintain the flexibility to make use of all their energy resources.

Our analysis proves that the nation can achieve deep reductions in greenhouse gas emissions without picking winners or losers. Some analysts have characterized the regulation of greenhouse gases as a war on coal (Martinson 2013). In fact, however, relying on energy efficiency allows states to reduce pollution and still take advantage of a full range of natural resources. States have a mix of resources to choose from; some have coal, while others make use of hydropower, nuclear, wind or natural gas. All have massive amounts of untapped energy efficiency resources. End-use energy efficiency simply reduces the demand for electricity; it is agnostic as to what generation sources are displaced. When demand is reduced, the remaining amount of electricity consumed will usually be supplied by the lowest bidder, regardless of fuel type. The real winners are the states themselves.

3. The policies and technologies included in our analysis have already been tested and are deployable now. The benefits can be quantified. There is no need to delay.

Our scenarios are based on what has already been achieved by a substantial number of states. Many of them have already begun implementing the four policy scenarios and have a wealth of experience to rely on. For example, states have been implementing successful efficiency policies and programs for decades. Twenty-six currently have energy efficiency resource standards in place, and many others have utility-run energy efficiency programs. More than 40 states have adopted some version of the national model building codes. CHP currently represents 8% of our national electric generating capacity (WEC 2013). Existing appliance standards saved the country at least $34 billion in 2010 alone (ASAP 2011).

Moreover we have been conservative in estimating new program implementation rates. For example, we assume a gradual ramp-up of energy savings targets in states that do not already have a target in place, and we estimate savings from equipment standards at a natural rate of turnover. In spite of these conservative estimates, we find that our policy scenario would result in massive pollution reductions between 2016 and 2030.

Focus on States

States play a significant role under Section 111(d). Once EPA has determined an emissions guideline, each state must develop a plan to achieve the standard.

All states would come out ahead under our efficiency scenario. Every state could reduce unemployment, strengthen its economy, and improve the health of its citizens. The following section includes a snapshot of the effect of adopting the four efficiency policies in Missouri, Ohio, and Virginia. Results for all states are included in Appendix C.

MISSOURI

In 2012 Missouri consumed over 82 million MWh of electricity (EIA 2013). Coal-fired plants generated over 79% of the state's power that year. Nuclear power was responsible for over 11% of Missouri's electricity, and less than 7% was generated from natural gas. Missouri has 20 coal-fired electric generators with a total nameplate capacity of 12,622 MW.

Missouri's electric power sector is responsible for nearly 89,756,000 tons of carbon dioxide per year, about 67,000 tons of nitrogen oxides, and almost 190,000 tons of sulfur dioxide. The state's power plants generate the eighth highest amount of carbon dioxide emissions in the country.

Based on gross state product, Missouri has the 22nd largest economy in the nation (usgovernmentrevenue.com 2014). Its unemployment rate was 6.5% in 2013, below the national average (BLS 2014b).

In recent years Missouri has begun to realize the benefits of energy efficiency for its economy and environmental quality. In 2009 the state adopted the Missouri Energy Efficiency Investment Act, which requires Missouri's investor-owned electric utilities to capture all cost-effective energy efficiency opportunities. The Act also puts in place a voluntary energy savings goal of 0.3% in 2012, ramping up to 0.9% in 2015, with a goal of 9.9% cumulative energy savings by 2020. Missouri has adopted the 2009 residential and 2007 commercial building energy codes. It has not adopted its own equipment standards.

Missouri should adopt a mandatory energy savings goal to expand the economic, environmental, and societal benefits it could be receiving from energy efficiency programs. The state would also garner significant benefits if it updated its model building codes and adopted standards for equipment not regulated by the federal government.

What would these policy improvements do for Missouri?

Together, these policies would avoid 15,000,000 tons of carbon dioxide in 2030, over $2,000,000 lost from missed work days, and over 3,100 asthma attacks.[33] They would also save the state money. The estimated average cost of electricity in Missouri is currently 8.5 cents per kWh. The efficiency policies would cost less per kWh, would create new jobs in the state, and would save Missouri $1.4 billion in 2030. Table 9 lists some of the energy

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[33] Calculated using EPA's COBRA Screening Model (EPA 2013).

impacts the policies would have on Missouri, and table 10 shows the pollution that would be avoided by implementing the policies.

Table 9. Energy impacts of efficiency policies in Missouri

Policy	Annual energy savings (MWh)	Cumulative energy saving (MWh)
	2020	
Energy savings target	3,933,000	9,699,000
Building codes	644,000	1,755,000
Combined heat and power	62,000	172,000
Equipment standards	130,000	476,000
	2030	
Energy savings target	14,392,000	111,299,000
Building codes	2,801,000	18,955,000
Combined heat and power	179,000	1,519,000
Equipment standards	183,000	2,177,000

Table 10. Emissions impacts of efficiency policies in Missouri (tons)

Pollutant	2020	2030
SO_2	6,000	23,000
NO_x	4,000	14,000
CO_2	4,000,000	15,000,000

OHIO

In 2012 Ohio consumed over 152 million MWH hours of electricity (EIA 2013). Coal-fired plants generated over 66% of the power in the state. Nuclear power was responsible for 13% of Ohio's electricity, and over 17% was generated from natural gas. Ohio has 25 coal-fired electric generators with a total nameplate capacity of 22,670 MW.

Ohio's electric power sector is responsible for over 123,810,000 tons of carbon dioxide per year, 134,000 tons of nitrogen oxides, and 679,000 tons of sulfur dioxide. Ohio's power plants generate the fourth highest amount of carbon dioxide emissions in the country.

Based on gross state product, Ohio has the seventh largest economy in the nation (usgovernmentrevenue.com 2014). Its 2013 unemployment rate was 7.4% (BLS 2014b).

Ohio is well on its way to realizing substantial economic and environmental benefits from its energy efficiency policies. The state has adopted a cumulative savings target of 22% by 2025. The annual target has been gradually ramping up and is set to achieve a savings of 1% per year in 2014 and 2% per year beginning in 2019. Ohio has adopted 2009 residential and 2007 commercial building energy codes. The state has not adopted its own equipment standards.

While Ohio has shown forward thinking and sound planning by adopting an energy savings target, there are still many improvements the state could make to increase the economic and environmental benefits of its efficiency policies. For example, Ohio should expand its energy savings target to cover all electric generation and extend its goal beyond 2025. The state would also see significant benefits if it updated its model building energy codes and adopted standards for equipment not regulated by the federal government.

What would these policy improvements do for Ohio?

Ohio's prominent industrial sector is one of its greatest efficiency opportunities; CHP has great potential in the state. Ohio could be generating 949,000 MWh of electricity by investing in cost-effective CHP. If all four policies were adopted, the state would avoid the emission of 27,000,000 tons of carbon dioxide, over $8,000,000 lost from missed work days and over 12,000 asthma attacks.[34] The policies would also reduce electricity bills for Ohio consumers—who currently pay an average of 9 cents per kWh, saving Ohioans $3.3 billion in 2030. Table 11 lists some of the energy impacts the policies would have on Ohio, and table 12 shows the pollution that would be avoided by implementing these policies.

Table 11. Energy impacts of efficiency policies in Ohio

Policy	Annual energy savings (MWh)	Cumulative energy saving (MWh)
	2020	
Energy savings target	11,233,000	32,830,000
Building codes	885,000	2,365,000
Combined heat and power	307,000	852,000
Equipment standards	248,000	911,000
	2030	
Energy savings target	29,317,000	256,093,000
Building codes	3,782,000	27,181,000
Combined heat and power	949,000	7,613,000
Equipment standards	349,000	4,163,000

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[34] Calculated using EPA's COBRA Screening Model (EPA 2013).

Table 12. Emissions impacts of efficiency policies in Ohio (tons)

Pollutant	2020	2030
SO_2	23,000	63,000
NO_x	9,000	23,000
CO_2	10,000,000	27,000,000

VIRGINIA

In 2012 Virginia consumed over 107 million MWh of electricity (EIA 2013). Roughly 20% of its power was generated by coal-fired power plants. Nuclear power was responsible for over 42% of Virginia's electricity, and about 35% was generated from natural gas. The state has 13 coal-fired electric generators with a total nameplate capacity of 5,770 MW.

Virginia's electric power sector is responsible for over 35,975,000 tons of carbon dioxide per year, over 48,000 tons of nitrogen oxides, and more than 95,000 tons of sulfur dioxide. Its power plants emit the 28th highest amount of carbon dioxide in the country.

Virginia has the 10th largest economy in the nation based on gross state product (usgovernmentrevenue.com 2014). Its unemployment rate was 5.5% in 2013 (BLS 2014b).

While Virginia has made some progress, there is room for improvement when it comes to realizing significant economic and environmental benefits from its energy efficiency policies. The state has a voluntary savings target of 10% by 2022. However, because the standard is voluntary, it has become largely symbolic, with Virginia utilities saving only 0.1% in 2011. The state should implement a mandatory energy savings target to cover all electric generation. Virginia would also see significant benefits if it strengthened its model building codes and adopted standards for equipment not regulated by the federal government. While the state has adopted 2009 residential and 2007 commercial building energy codes, it does not have its own standards for equipment.

What would these policy improvements do for Virginia?

Together, these policies would avoid 17,000,000 tons of carbon dioxide in 2030, nearly $4,000,000 lost from missed work days and over 5,500 asthma attacks.[35] They would also save money. The average cost of electricity in Virginia is currently estimated at around 9 cents per kWh. The policies would cost less per kWh, create new jobs in the state, and save Virginia $2 billion in 2030. Table 13 lists some of the energy impacts the policies would have in Virginia, and table 14 shows the pollution that would be avoided.

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[35] Calculated using EPA's COBRA Screening Model (EPA 2013).

Table 13. Energy impacts of efficiency policies in Virginia

Policy	Annual energy savings (MWh)	Cumulative energy saving (MWh)
	2020	
Energy savings target	4,243,000	9,835,000
Building codes	878,000	2,431,000
Combined heat and power	291,000	808,000
Equipment standards	174,000	641,000
	2030	
Energy savings target	19,605,000	141,652,000
Building codes	3,641,000	26,408,000
Combined heat and power	766,000	6,624,000
Equipment standards	244,000	2,912,000

Table 14. Emissions impacts of efficiency policies in Virginia (tons)

Pollutant	2020	2030
SO_2	6,000	25,000
NO_x	3,000	13,000
CO_2	4,000,000	17,000,000

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Appendix A. Jobs Analysis

METHODOLOGY OF THE MACROECONOMIC MODEL

To evaluate the macroeconomic impacts of a variety of energy efficiency, renewable energy, and climate policies at the local, state, and national level, ACEEE uses the proprietary Dynamic Energy Efficiency Policy Evaluation Routine, or DEEPER model. The model has a 20-year history of use and development, though it was more recently renamed "DEEPER."

The DEEPER modeling system is a 15-sector quasi-dynamic input-output (I/O) model of the U.S. economy that draws upon social accounting matrices from the Minnesota IMPLAN Group, energy use data from the U.S. Energy Information Administration's Annual Energy Outlook (AEO), and employment and labor data from the Bureau of Labor Statistics (BLS).[36] The Excel-based tool is made up of three linked modules: (1) the energy and emissions module (2) the electricity production module, and (3) the macroeconomic module.[37] DEEPER contains approximately two dozen interdependent worksheets. The model functions as laid out in the flow diagram (figure A1) below:

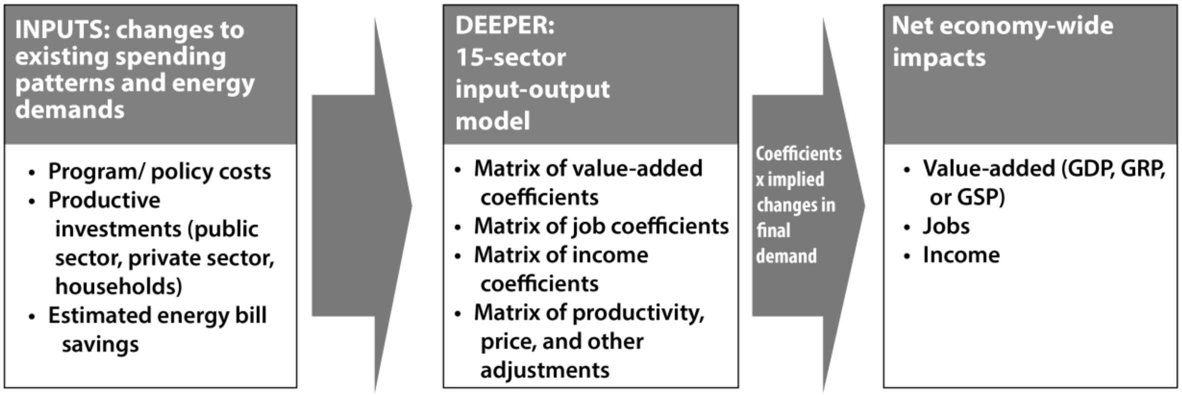

Figure A1. The DEEPER model

DEEPER results are driven by adjustments to energy service demands and by alternative investment patterns resulting from projected changes in policies and prices between baseline and policy scenarios. The model is capable of evaluating policies at the national level through 2050. However, given uncertainty surrounding future economic conditions and the life of the impacts resulting from the policies analyzed, DEEPER is often used to

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[36] The current mix of 15 sectors reflects the analyst's efforts to exhibit key outcomes while maintaining a model of manageable size. It is possible to expand and reduce the number of sectors in the model with relatively easy programming adjustments. If the analyst chooses to reflect a different mix of sectors and stay within the 15 x 15 matrix, that can be easily accomplished through minor changes. Input-output models use economic data to study the relationships among producers, suppliers, and consumers. They are often used to show how interactions among all three impact the macroeconomy. A social accounting matrix is a data framework for an economy that represents how different institutions—households, industries, businesses, and governments—all trade goods and services with one another. See http://implan.com/V4/Index.php. The entire IMPLAN database for the U.S. economy can be expanded to more than 400 sectors as needed.

[37] See Laitner, Bernow, and DeCicco (1998) for an example of an earlier set of modeling results. For a more recent review of modeling assessments, see Laitner and McKinney (2008).

evaluate out 10–15 years. Although like most I/O models, DEEPER is not a general equilibrium model, it does provide accounting detail that balances changes in investments and expenditures within a sector of the economy.[38] With consideration for goods or services that are imported, it balances the variety of changes across all sectors of the economy.[39]

The macroeconomic module contains the factors of production—including capital (or investment), labor, and energy resources—that drive the U.S. economy for a given base year. DEEPER uses a set of economic accounts that specify how different sectors of the economy buy (purchase inputs) from and sell (deliver outputs) to each other.[40]

The DEEPER model is typically used to evaluate impacts of selected policies in 15 different economic sectors that are usually affected by changes in energy use and investment: agriculture, oil and gas extraction, coal mining, other mining, electric utilities, natural gas distribution, construction, manufacturing, wholesale trade, transportation and other public utilities (including water and sewage), retail trade, services, finance, government, and households.[41] The model looks at different labor intensities in different sectors to provide insights about the net employment benefits to the economy.[42]

The macroeconomic module translates the different selected policy scenarios, including necessary program spending and research and development (R&D) expenditures, into an annual array of physical energy impacts, investment flows, and energy expenditures over the desired period of analysis. DEEPER evaluates the policy-driven investment path for the various financing strategies, as well as the net energy bill savings anticipated over the study period. It also evaluates the impacts of avoided or reduced investments and expenditures otherwise required by the electric and natural gas sectors. These quantities and expenditures feed directly into the final-demand worksheet of the module that generates the net changes in sector spending.

The resulting positive and negative changes in spending and investments in each year are converted into sector-specific changes in aggregate demand.[43] These results then drive the I/O matrices utilizing a predictive algebraic expression known as the Leontief inverse

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[38] General equilibrium models operate on the assumption that a set of prices exists for an economy to ensure that supply and demand are in an overall equilibrium.

[39] When both equilibrium and dynamic input-output models use the same technology assumptions, both models should generate a reasonably comparable set of outcomes. See Hanson and Laitner (2005) for a diagnostic assessment that reached that conclusion.

[40] Further details on this set of linkages can be found in Hanson and Laitner (2009).

[41] Household spending is allocated to each of the sectors using the personal consumption expenditure data provided in the IMPLAN data set.

[42] This is the magnitude of jobs supported by a given level of investment.

[43] This is the total demand for final goods and services in the economy at a given time and price level.

matrix, which drives the input-output model according to the following predictive equation:[44]

$X = (I-A)^{-1} * Y$

where:

X = total industry output by sector

I = an identity matrix consisting of a series of 0's and 1's in a row and column format for each sector (with the 1's organized along the diagonal of the matrix)

A = the matrix of production coefficients for each row and column within the matrix (in effect, how each column buys products from other sectors and how each row sells products to all other sectors)

Y = final demand, which is a column of net changes in spending by each sector as that spending pattern is affected by the policy case assumptions (changes in energy prices, energy consumption, investments, and so on)

This set of relationships can also be interpreted as

$\Delta X = (I-A)^{-1} * \Delta Y$

which reads, A change in total sector output equals the expression $(I-A)^{-1}$ times a change in final demand for each sector.[45]

Employment quantities are adjusted annually according to assumptions about the anticipated labor productivity improvements based on forecasts from BLS. The DEEPER macroeconomic module traces how changes in spending will ripple through the U.S. economy in each year of the assessment period.

The end result is a net change between the reference and policy scenarios in jobs, income, and value added, which is typically measured as gross domestic product (GDP), gross state product (GSP), or gross regional product (GRP) depending on the study region.[46]

Like all economic models, DEEPER has strengths and weaknesses. It is robust by comparison to some I/O models because it can account for price and quantity changes over time and is sensitive to shifts in investment flows. It also reflects sector-specific labor intensities across the U.S economy. However it is important to remember when interpreting

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[44] For a more complete discussion of these concepts, see Miller and Blair (1985).

[45] Perhaps one way to understand the notation $(I-A)^{-1}$ is to think of this as the positive or negative impact multiplier depending on whether the change in spending is positive or negative for a given sector within a given year.

[46] This is the market value of all final goods and services produced within a geographic area in a given period.

results for the DEEPER model that they rely heavily on the quality of the information provided and the modeler's own assumptions and judgment. The results are unique to the specified policy design. The results reflect differences among scenarios in a future year, and like any prediction of the future, they are subject to uncertainty.

HOW DEEPER EVALUATES POLICY ALTERNATIVES

As described above, ACEEE's DEEPER model uses principles of input-output (I/O) modeling to evaluate the economic impacts of various policy alternatives. This section gives additional detail on how it handles data and produces results.

The core of the DEEPER model is the A-matrix or direct requirements matrix. This relates industries to one another, detailing how much input from one industry is required to make a dollar's worth of output from another industry. The L-matrix (or Leontief inverse) multiplied by a final demand vector will return the amount of output from each industry that is required to support that level of final demand, where final demand is the use of goods and services by end users, as opposed to inputs to other production processes. For any given increase in final demand of goods and services, it is conceptually straightforward to determine how much additional output each industry would have to create to meet this increase.

A second critical component of DEEPER is the set of multipliers that convert the resulting increases in output into (1) the amount of employment needed to generate that increase in output, (2) how much income that would generate for workers, and (3) how much GDP that would create (or value added, the state-level equivalent of GDP). DEEPER uses data from the IMPLAN Group for its national- and state-level A-matrices and multipliers.

DEEPER breaks the economy down into 14 goods- and services-producing industries and the household sector. We break the IMPLAN data into those industries and extract 51 state-level and one national A-matrix and set of multipliers.[47] For each state, we then set about generating a set of final demand changes. These come from research by ACEEE technical experts into the impacts of investments in energy efficiency on energy consumption. We translate those changes in energy consumption from physical units to dollars using price projections from the AEO for 2013 (EIA 2013b).

The two sets of essential inputs generated by our technical analysis are: (1) the amount of expenditure required by each sector to drive the energy efficiency investments we analyzed and, (2) the energy savings those investments generate over what time profile.

The expenditure data is associated with one of three broad sectors of the economy: households and the commercial and industrial sectors. For each of the efficiency investments, we determined how much expenditure would be required by each sector to support the investments. In cases where we examined programs that were administered by utilities, we assumed that the utilities would cover the costs of the programs by raising rates for those sectors benefitting from the programs on a pro-rata basis. We assumed that

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[47] For our purposes we treat the District of Columbia as though it were a state.

households and businesses reduced their expenditures on other goods and services sufficiently to cover these increased expenses, and that those reduced expenditures reduced payments to various sectors on a pro-rata basis according to historical spending patterns derived from IMPLAN.

The investments in efficiency were allocated to the construction, manufacturing, and service industries depending on the type of investment made. For example, we assumed that investments in building retrofits were spent largely on the construction industry. Some investments required a large up-front expense that, in our judgment, was likely to be financed rather than paid out of pocket. In these instances, we chose an interest rate and loan tenor that matched the borrower and type of project. We calculated the interest payments on the financing under these terms and allocated that spending to the financial sector.

The model then takes the energy savings in dollar terms, allocated by sector, and breaks them down as increased expenditures by those sectors. Those increased expenditures are sub-allocated among the goods- and services-producing industries based on historical expenditure patterns.

We aggregated all of these changes in spending flows as net changes to final demand by the 14 industries and the household sector, applied those changes in final demand to the Leontief matrix described above, and generated employment, income, and GDP/value-added estimates using the appropriate multipliers. We adjusted the employment results by applying sector-specific labor productivity growth factors based on historical data from BLS. So, for example, while the construction sector may support almost 9 full-time equivalent job-years per million dollars of revenue in 2011, by 2030 that same (inflation-adjusted) one million dollars of revenue will only require about 6.5 full-time equivalents to produce.

In generating the national-level analysis, we accounted for international trade by using regional purchase coefficients that indicate how much of each type of good and service consumed in the United States is also produced here. That share of the increased final demand was assumed to remain domestically, while the rest was assumed to go toward purchasing imported goods and to produce no employment or income gains for the country.

We used a similar approach at the state level, where we assumed that increased expenditures by households and companies in a given state were spent within that state according to historic trends. We assumed that the historic share of consumption going to out-of-state purchases applied to increased demand generated by the efficiency investments we analyzed. For some states, the share of energy savings and efficiency investments that were spent in the state were as low as about 60%, while others were closer to 75%. We made no adjustments to the model to account for increased exports to other states resulting from their increased expenditures due to efficiency investments or energy savings. We took this approach to give individual states our best assessment of the impacts that efficiency investments would have on them regardless of what other states did or did not do. Accordingly, we modeled the fact that in-state consumers and businesses would spend a significant share of their expenditures and savings in other states, while relegating the effects of other states' behavior to the implicit baseline over which an individual state has no influence.

The one exception to this is the electricity industry. Any given individual state is likely both to import and to export substantial amounts of electricity. Some, like California, may export very little (perhaps none at all) and import a good deal, while other states, like Pennsylvania, certainly export a significant amount of electricity and may import very little. To adjust the model appropriately to account for interstate electricity trade, we would need to have estimates of each state's gross imports. Using that data, we could assign reduced utility revenues to the state in question based on what share of electricity it supplies for itself, and we could assign the rest to other states. This type of adjustment would be consistent with our treatment of other goods and services.

Unfortunately, neither part of this analysis is possible. The electricity grid was built along physical and economic lines with little regard for states' political boundaries. The Energy Information Administration collects and reports data on net generation by state and net electricity sales by state, and one can estimate net electricity imports by subtracting one from another. However, this netting will not reveal the gross electricity import data that is required to do the trade adjustment. States that straddle multiple sections of the grid, like Illinois, may export large quantities of electricity from one part of the state while importing large quantities into another. The net imports might be close to zero, masking the true nature of the market. Using net imports as a proxy for gross imports is as likely to degrade the accuracy of our projections as it is to improve it.

Given this restriction, we opted to assume that all electric utility revenue losses would accrue in the state in which electricity demand is reduced. For the individual state analyses, this biases our employment and other projections downward. Utilities in a state like Maryland with gross imports that might be above 40% of total consumption should only lose 60% of the decreased revenues resulting from the energy savings. However, our handling of the data limitations means that 100% of the reduced demand in Maryland translates into reduced revenues for Maryland utilities. At the same time, for electricity-exporting states like Pennsylvania, our assumption that 100% of the reduced electricity demand translates into reduced revenues for in-state utilities is probably close to accurate since Pennsylvania generates significantly more electricity than it needs. The net impact of these assumptions is neutral in some states and biases our results downward in others. Though somewhat unsatisfying, this result is preferable to the option of using net imports, which would bias our results in different directions for different states, with the direction and even the existence of the bias not always being known.

With these caveats in mind, we believe that our results represent a reasonable estimate of the impacts of efficiency investments on the national and state-level economies.

Appendix B. Calculations, Assumptions, and Sources

This appendix presents the data sources and assumptions we used for this analysis. Categories include net costs, energy savings targets, building energy codes, combined heat and power (CHP), and appliance standards.

CALCULATION OF NET COSTS

Net costs reported are the difference between the investments required to implement the measure or policy and dollars of energy savings. Costs include interest costs for any investments that were financed and in some cases ongoing administrative costs (energy savings target and building energy codes) and operating costs (CHP). Some or all of the investment is financed for some policies; in that case costs are treated as payments on a loan rather than as a one-time investment. Annual costs reflect the costs incurred in the reported year due to policies and measures implemented in that same year, plus payments due in the reported year for policies and measures implemented in prior years. Cumulative costs reflect a sum of the annual costs for the reported year and prior years.

Dollars of energy savings are calculated from the energy savings based on projected sectorial energy prices. For CHP the increased use of natural gas reduces the energy and dollar savings.[48] Annual energy savings are those savings that accrue in the reported year due to new measures and policies in that year and to the measures and policies implemented in prior years (if the measure lifetimes have not expired). Cumulative energy savings are the sum of annual savings in the reporting year and all prior years of the policy or measure.

These calculations include new measures through 2030. All dollar amounts are in constant 2011 dollars. The present values are calculated using a 5% real discount rate.

Electricity prices (and natural gas where applicable) start from EIA data by sector and state for 2011. They are calculated using projected annual changes for each sector and region from EIA's Annual Energy Outlook. To estimate the regional changes in electricity prices, we linearly projected beyond 2040 by taking the average annual change from 2020 to 2040. We made adjustments to the forecasts in certain states to correct anomalies in the data. In Delaware and Pennsylvania, we used the 2010 price as a baseline instead of 2011; in Kentucky, we modified electricity prices to more closely match a price forecast put together by the Kentucky Department for Energy Development and Independence (with assistance from ACEEE) that accounted for higher electricity prices expected in the future.

The benefit-cost ratios are the present value of the cumulative dollar savings divided by the present value of the cumulative costs.

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[48] Gas savings from building energy codes are not reflected in the energy savings reported in this analysis.

ANNUAL ENERGY SAVINGS TARGETS

One of the most common and effective ways for states to take advantage of energy efficiency resources is to set a target for utilities or non-utility program implementers to achieve a certain amount of energy savings. This goal can come from the adoption of legislation or through regulation, and it can be applied to a statewide program implementer, to specific utilities, or to a combination of program implementers. Currently, 26 states have adopted an energy efficiency resource standard (EERS), which ACEEE defines as a long-term (3+ years), binding energy savings target for utilities or non-utility program administrators. Additional states have utilities that operate energy efficiency programs while the states themselves do not have predetermined and binding multiyear savings targets. More information on the annual savings goals required in those states can be found in the ACEEE *2013 State Energy Efficiency Scorecard* and our state energy efficiency policy database (http://www.aceee.org/sector/state-policy).

Nearly all states have some utility-sector energy efficiency programs, and their commitment to and investment in these programs have increased dramatically in recent years.[49] Electricity program spending or budgets have increased more than three-fold since 2006. Figure B1 shows the change in national spending on energy efficiency by utilities since the 1990s.

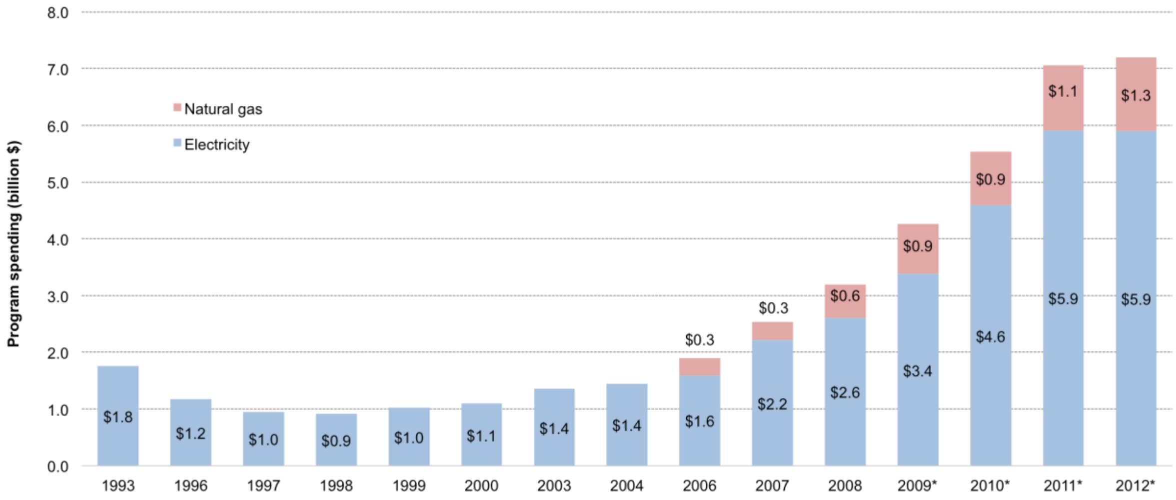

Figure B1. Annual energy efficiency spending. From 1993 to 2008, values represent actual program spending (including customer-funded programs); from 2009 on, they represent program budgets. Natural gas spending is not available for 1993-2004. For sources see http://www.aceee.org/sites/default/files/publications/researchreports/e13k.pdf.

In most states, annual targets have increased over time, and approximately five states now have goals that achieve or will achieve incremental savings equal to 2% of total sales per

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[49] By utility-sector energy efficiency programs, we mean programs funded through utility rates (whether embedded in rates or as a separate tariff rider or surcharge) or through associated public-benefits charges, and administered by utilities, government agencies, or third-party organizations.

year. An additional six states have goals that will achieve savings equal to 1.5% of total sales per year. Table B1 shows state savings targets.

Table B1. State savings targets

Approximate annual savings target in 2013	Number of states	States
2% or greater	5	Massachusetts, Arizona, Rhode Island, New York, Vermont
1.5% - 1.99%	6	Illinois, Maryland, Maine, Minnesota, Colorado, Indiana
1.0% - 1.49%	9	Connecticut, Iowa, Oregon, Washington, Hawaii, Ohio, New Mexico, Michigan
0.5% - 0.99%	4	California, Wisconsin, Pennsylvania, North Carolina, Arkansas

Nevada has a savings target of 0.2% and Texas has a target of 0.1%. *Source:* http://www.aceee.org/sites/default/files/publications/researchreports/e13k.pdf.

For purposes of this analysis, we assume that all states ramp up to a 1.5% statewide annual savings target as described in more detail below.

This analysis assumes the following energy efficiency resource standard scenario:

- Each state adopts a statewide savings target that ramps up to 1.5% of sales per year relative to the forecasted sales for that state in the previous year. This means that each year the state will achieve new savings equal to 1.5% of demand for the previous year. For all states, we start ramping up in 2016 from actual statewide 2011 or 2012 (as available) electricity savings levels, the data for which we take from our *2013 State Energy Efficiency Scorecard*. If 2011 savings levels are below 0.25%, we assume the state begins at 0.25%. If a state is currently achieving less than 1.5%, we assume a ramp-up of 0.25% per year until 1.5% is achieved; 1.5% then remains the constant annual savings through 2030. For example, a state that is currently achieving 1% savings per year would achieve 1% in 2016, 1.25% in 2017, and 1.5% in 2018 and each year thereafter through 2030.
- If a state is currently achieving or plans to achieve savings higher than 1.5%, those savings would be additional to our scenario and are therefore not included.
- The annual savings target of 1.5% is achieved relative to the forecasted sales in that year. We applied regional forecasted percentage changes in sales to actual sales for each state and adjusted those forecasts based on savings that would be achieved under this policy scenario.
- Many states with existing savings targets limit the portion of statewide energy sales applicable to the policy. For example, the targets may apply only to sales from investor-owned utilities and not to cooperative or municipal utilities. We assume that the targets apply to 100% of statewide sales starting in 2016, and the ramp-up starts from overall statewide savings.
- Cost estimates are based on data collection of actual spending in 18 states.

Calculations

Incremental annual energy savings = Annual forecasted electricity sales by sector * Annual savings target

Annual energy savings = Incremental annual energy savings$_{y}$ + Annual energy savings$_{y-1}$

Cumulative energy savings = Annual energy savings$_{y}$ + Cumulative energy savings$_{y-1}$

Annual cost savings = Annual energy savings by sector * Average retail rate by sector

Investment by sector = Incremental annual energy savings * (Customer cost/kWh + Utility incentive cost/kWh)

Spending (annualized expenditures) by sector = Σ (Financing payments by sector) + (Investment * (1 - Financing percentage)) except for utility expenditures, which = Σ (Financing payments by sector)

Terms and Data Sources

Annual forecasted electricity sales uses retail electricity sales by state for the residential, commercial, and industrial sectors in 2012 and applies annual sector-specific growth rates to estimate forecasted sales. *Source:* EIA 861, http://www.eia.gov/electricity/data.cfm.

Adjusted electricity sales forecast takes the value for year Y from the above forecast and subtracts the *Annual energy savings by sector* in year Y.

Annual savings target represents up to 1.5% of new (incremental) energy savings each year relative to forecasted annual sales. In states where 1.5% or greater energy savings have been achieved as of 2011 we assume savings of 1.5% per year beginning in 2016. States that have not yet reached 1.5% savings will ramp up to 1.5% savings at a rate of 0.25% per year. For all states, 2016 annual savings targets begin at 2011 or 2012 actual savings levels (with a 0.25% minimum) and ramp up by 0.25% after that to the maximum 1.5%.

Annual energy savings by sector is the sum of all the *Annual incremental energy savings*; i.e., the sum of the *Annual incremental energy savings* in year Y and the *Annual energy savings* in year Y-1.

Average retail rate by sector is the retail electricity rate paid by customers by sector, and is forecast using data from the EIA. *Source:* EIA 861 http://www.eia.gov/electricity/data.cfm.

Utility program costs/kWh is based on total program costs per kWh for a utility. These costs vary by state. For this analysis, we divide states into two tiers. Tier 1 states have been implementing energy efficiency programs for at least a decade, while Tier 2 states are new to comprehensive efficiency programs or are still ramping up from lower levels. First-year cost for Tier 1 states is $0.32 per first-year kWh. First-year cost for Tier 2 states is $0.17 per first-year kWh. Beginning in 2021, we assume that all Tier 2 states' first-year costs increase to Tier 1 levels; i.e., the first-year costs for all states are set at Tier 1 levels beginning in 2021. Cost assumptions are based on preliminary data from Molina (2014).

Tier 1 is the average of VT, OR, CA, MA, RI, MN, IA and CT, and Tier 2 is the average of AZ, CO, IL, MI, NM, and NV, TX, and UT. From 2016-2021, Tier 2 states are AL, AK, AZ, AR, CO, DE, DC, FL, GA, ID, IL, IN, KS, KY, LA, ME, MD, MI, MS, MO, MT, NE, NV, NH, NJ, NM, NC, ND, OH, OK, PA, SC, SD, TN, TX, UT, VA, WA, WV, and WY.

Utility program incentive costs/kWh is the amount of money the utility invests in customer incentives per kWh of electricity saved. We assume that 80% of total program costs are incentives paid to customers for technologies or services. For Tier 1 states this is $0.26/kWh ($0.32/kWh*80%). For Tier 2 states these costs are $0.14/kWh.

Utility program admin costs/kWh is the amount of money a utility invests in program administration per unit of electricity saved. We assume that program administrative costs are 20% of total program costs. For Tier 1 states this is $0.06/kWh. For Tier 2 states this is $0.03/kWh.

Customer cost/kWh is the amount of money that customers invest when they participate in a utility-run energy efficiency program. We assume that utilities and customers split technology costs evenly, so that customers contribute the same amount as utility program incentives. For Tier 1 states this is $0.26/kWh. For Tier 2 states this is $0.14/kWh.

Assumptions

Measure life is assumed to be 13 years for commercial and industrial measures. We assume eight years for residential measures.

Degradation of savings assumes that, for the later years when installed measures come to the end of their measure lives, we subtract the *Annual incremental energy savings* realized in year Y from the *Annual energy savings* in year Y+8 for residential and year Y+13 for commercial and industrial. However, we assume that only 50% of the *Annual incremental energy savings* from any year are subtracted, due to the assumption that customers replace 50% of the expired savings measures from out of pocket, i.e., without incentives from utilities.

Financing percentage is the portion of energy efficiency investments that are not paid for by cash or credit card; rather, they are financed through loans and so on, and therefore incur interest over time. We assume that 20% of measure investments across all sectors are financed and that this value does not change over time. Because we assume that utilities and customers split technology costs evenly, the portion of investments that are financed are split 50/50 between utilities and customers, to take into account different interest rate structures. We assume 100% of program administration costs are financed.

BUILDING CODES

Buildings are a very large potential source of electricity savings, as they consume over 70% of U.S. electricity. Building codes establish minimum requirements for the design and construction of new and renovated residential and commercial buildings. States have the authority to adopt building codes, which are generally based on model codes developed by national consensus standards organizations. The International Code Council develops the International Energy Conservation Code (IECC)—the national residential model code—and updates it every three years. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) updates model commercial codes (ASHRAE Standard 90.1) every three years. The most recent national model codes date from 2012 and 2010 for residential and commercial buildings respectively. While many states have been leaders, not all states have adopted model building codes, and almost all states are several years behind in adopting the most recent codes.

Only electricity savings are included in energy savings, but financial impacts include natural gas savings in annual monetary savings. As for the other policies, annual savings are the sum of incremental savings for measures that are still in effect. Annual savings in the year a new home is built are assumed to be half of incremental energy savings for a year. All executed energy saving measures that are completed as a result of improved building codes are assumed to have an effective measure life of 40 years. All costs are assumed to be financed in 30-year loans using mortgage and commercial interest rates.

Calculations

Incremental annual electricity savings in new residential buildings at code = Electric intensity of residential buildings * Square feet of new homes constructed * % of savings from code * % of electricity use covered by codes * % of energy savings realized[50]

Incremental annual natural gas savings in new residential buildings at code = Natural gas intensity of residential buildings * Square feet of new homes constructed * % of savings from code * % of natural gas use covered by codes * % of energy savings realized

Additional cost for residential buildings = (Additional cost per home * Number of new homes) + Cost of administration

Terms and Assumptions

Electric intensity of residential buildings is the average kWh consumed per square foot of single-family and multifamily homes built from 2000 to 2009, by small regions. For each of four regions, the Residential Energy Consumption Survey (RECS) gives the average electric intensity by subregion, building type, and age of home (separately). To combine them we multiplied the intensity for a subregion by the ratios of the intensities for single/multifamily and for new homes to the overall intensity for the larger region. *Source:* RECS, Summary Household Site Consumption and Expenditures by Region, 2000-2009. http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption#summary.

Natural gas intensity of residential buildings is the average kbtu consumed per square foot of single-family and multifamily homes built from 2000 to 2009, by small region. As we did for electricity, we multiplied the average natural gas intensity for all homes in a subregion by the ratios of the intensities for single/multifamily and for new homes to the overall intensity for the larger region. *Source:* RECS, Summary Household Site Consumption and

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[50] Our residential building codes analysis distinguishes between single-family and multifamily residential buildings for both savings and costs.

Expenditures by Region, 2000-2009.
http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption#summary.

Square feet of new homes constructed is the square footage of all new homes per year, by state. We derive the number of new homes by multiplying the portion of new units completed in a state, relative to total U.S. completions (from Moody's) by total new units nationwide as estimated by EIA. Then we multiply the number of new units annually by state by the average square foot of a unit (either single-family or multifamily) constructed in 2012, adjusted by region. We make this adjustment by multiplying the average regional square footage of a home constructed in 2012 by the ratio of average home square footage in a small region to average square footage in the larger region. Sources are:

- Moody's Analytics, New unit completions by year, by housing type, by state, 2010-2030, https://www.economy.com/default.asp.
- AEO, Table A-4 Residential Sector Key Indicators Total Households, 2013, http://www.eia.gov/forecasts/aeo/pdf/tbla4.pdf.
- Average new unit size, U.S. Census Bureau, 2012, http://www.census.gov/construction/chars/completed.html.[51]

Percentage of savings from code is the percentage improvement in energy savings that are anticipated to be achieved through the code.[52] We assign percent savings by dividing states into two groups based on the current status of their residential building codes. Group 1 represents states with either 2006 IECC in place, an earlier code, or no code. Group 2 represents states with 2009 IECC in place or a later code. Group 1 states are estimated to achieve energy savings of 25% to 38% when adopting the 2012 IECC, and 50% when adopting the 2021 IECC. Energy savings in Group 2 states range from roughly 12% to 28% when adopting the 2012 IECC, and from roughly 36% to 42% when adopting the 2021 IECC.

Energy savings from the implementation of the 2012 IECC for states in Group 1 are based on the percent avoided energy cost savings from building at 2012 IECC over 2006 IECC. Savings from 2012 IECC for states in Group 2 are the percent savings of 2012 IECC over 2006 code minus energy savings from the implementation of the 2009 IECC over 2006 code. For Group 2 states, 2021 IECC savings are the 50% savings assumed for Group 1 states, minus the percent difference between 2009 IECC and 2006 IECC, in order to account for the more advanced version of code they already have in place. *Source: Cost-Effectiveness Analysis of the 2009 and 2012 IECC Residential Provisions – Technical Support Document,* 2013, Table 8.3, 2012 savings over 2006 code,

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[51] Moody's requires a subscription.

[52] Percent savings are assumed to be identical for both electricity and natural gas.

http://www.energycodes.gov/sites/default/files/documents/State_CostEffectiveness_TSD_Final.pdf.

Percentage of electricity use covered by code is the ratio of electric end-use consumption covered by code compared to the total electric end-use consumption in homes by region. This value includes electricity consumed through space heating, water heating, air conditioning, and 10% of other end uses. The 10% of other end uses accounts for lighting that is covered by code. *Source:* RECS, Tables CE 4.2-CE4.5, 2009, http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption.

Percentage of natural gas use covered by code is the ratio of natural gas end-use consumption covered by code compared to the total natural gas end-use consumption in homes by region. This value includes natural gas consumed through space heating and water heating. *Source:* RECS, Tables CE 4.2-CE4.5, 2009, http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption.

Percentage of energy savings realized is the percentage of actual energy savings achieved relative to total potential energy savings achieved from building to the latest code. We placed states into one of three tiers based on compliance scores from the *2013 State Energy Efficiency Scorecard*. States that scored a 1.5 or higher (out of a possible two points) were assigned to Tier 1 and assumed to realize 95% energy savings. States that scored <1.5 points were placed in Tier 2 and assumed to realize 90% energy savings, ramping up to 95% between 2016 and 2021. States that scored <1 point were paced in Tier 3 and assumed to realize 85% energy savings, ramping up to 95% between 2016 and 2021. *Source: 2013 State Energy Efficiency Scorecard*.

Additional cost per home is the incremental average cost of construction per home above 2006 or 2009 codes (for Group 1 and Group 2 respectively) for both single-family and multifamily homes, for measures by climate zone with costs multiplied by construction cost factors by state. These values are then multiplied by the percentage of energy savings realized to adjust for homes that do not incur additional costs to meet the code. 2021 codes are assumed to cost double the cost of meeting 2012 IECC for each state. *Source: Cost-Effectiveness Analysis of the 2009 and 2012 IECC Residential Provisions – Technical Support Document*, http://www.energycodes.gov/sites/default/files/documents/State_CostEffectiveness_TSD_Final.pdf.

Cost of administration is the annual cost for code implementation, monitoring, and evaluation, by state. We assume this cost is $40 per home. *Source:* LBNL, *The Cost of Enforcing Building Energy Codes: Phase 2* (not yet published). The incremental cost of enforcing residential energy codes using a traditional review and inspection process ranges from $31 to $49 (above cost of health and safety code enforcement).

Calculations

Incremental annual electricity savings in new commercial buildings at code = Electric intensity of commercial buildings * Square feet of new commercial buildings * % savings from code * % of electricity use covered by codes * % of potential energy savings realized

Incremental annual natural gas savings in new commercial buildings at code = Natural gas intensity of commercial buildings * Square feet of new commercial buildings * % of savings from code * % of natural gas use covered by codes * % of energy savings realized

Additional cost for commercial buildings = Average simple payback * Incremental annual energy savings* Cost of energy + Cost of administration[53]

Terms and Data Sources

Electric intensity for commercial buildings is the average kWh of electricity consumed per square foot for commercial buildings by state. States were placed in two groups. For states with commercial building codes at or below the 2004 standard or with no commercial building code in place, we use the average electric intensity by region of commercial buildings constructed at the ASHRAE Standard 90.1-2004 as the baseline against which savings are estimated. For states with the 2007 or a later standard in place, we decrease the average electric intensity at 2004 code by 4.6% to reach the average electric intensity of commercial buildings constructed at the 2007 standard. Sources are as follows:

- Data from final determination of ASHRAE 90.1 2004, Quantitative analysis spreadsheet, http://www.energycodes.gov/regulations/determinations/previous.
- ANSI/ASHRAE/IESNA Standard 90.1-2007 Final Determination Quantitative Analysis Table 11.3, http://www.energycodes.gov/sites/default/files/documents/BECP_FinalQuantitativeAnalysisReport901-2007Determination_May2011_v00.pdf.

Natural gas intensity for commercial buildings is the average kbtu of natural gas consumed per square foot for commercial buildings by state. States were placed in two groups. For states with commercial building codes at or below the 2004 standard or with no commercial building code in place, we use the average natural gas intensity by region of commercial buildings constructed at the ASHRAE Standard 90.1-2004 as the baseline against which savings are estimated. For states with the 2007 or a later standard in place, we decrease the average natural gas intensity at 2004 code by 4.6% to reach the average electric intensity of commercial buildings constructed at the 2007 standard. Sources are:

- Data from final determination of ASHRAE 90.1 2004, Quantitative analysis spreadsheet, http://www.energycodes.gov/regulations/determinations/previous
- ANSI/ASHRAE/IESNA Standard 90.1-2007 Final Determination Quantitative Analysis Table 11.3, http://www.energycodes.gov/sites/default/files/documents/BECP_FinalQuantitativeAnalysisReport901-2007Determination_May2011_v00.pdf.

Percentage savings from code is the percent energy savings by region relative to ASHRAE 2004 or 2007, depending on a state's baseline, for ASHRAE 90.1-2010 code for years 2016-2019

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[53] For the purposes of our commercial buildings analysis, natural gas was factored into the calculations of incremental additional costs but not into energy savings calculations.

and ASHRAE 90.1-2016 for years 2020-2030. We assume 2016 code savings 50% relative to 90.1-2004. Sources are:

- PNNL, *Achieving the 30% Goal: Energy and Cost Savings Analysis of ASHRAE Standard 90.1-2010*, http://www.energycodes.gov/sites/default/files/documents/BECP_Energy_Cost_Savings_STD2010_May2011_v00.pdf.
- ANSI/ASHRAE/IESNA Standard 90.1-2007 Final Determination Quantitative Analysis Table 11.3, http://www.energycodes.gov/sites/default/files/documents/BECP_FinalQuantitativeAnalysisReport901-2007Determination_May2011_v00.pdf.

Percentage of electricity use covered by code is the percent of electricity for end uses covered by code relative to all commercial electricity consumption by census division. This includes space heating, cooling, ventilation, water heating, and lighting. *Source:* CBECS 2003, Table E3A, http://www.eia.gov/consumption/commercial/data/2003/index.cfm?view=consumption.

Percentage of natural gas use covered by code is the percent of natural gas for end uses covered by code relative to all commercial natural gas consumption by census division. This includes space heating and water heating. *Source:* CBECS 2003, Table E7, http://www.eia.gov/consumption/commercial/data/2003/index.cfm?view=consumption.

Square feet of new commercial buildings is the floor space of new construction by year by state. This value is reached by multiplying the portion of new private nonresidential construction spending in a state relative to total national spending projected by Moody's, by total new commercial floor space in the United States projected by EIA. *Source:* AEO 2013; Moody's Analytics, New Private, Non-Residential Construction Spending by State 2010-2030, https://www.economy.com/default.asp.

Percentage of potential energy savings realized is the percent of actual energy savings achieved relative to total potential energy savings achieved from building to the latest code. States were placed into one of three tiers based on compliance scores from the *2013 State Energy Efficiency Scorecard*. States that scored a 1.5 or higher (out of a possible two points) were assigned to Tier 1 with an assumed 95% energy savings realized. States that scored <1.5 points were placed in Tier 2 with an assumed 90% energy savings realized, ramping up to 95% between 2016-2021. States that scored <1 point were placed in Tier 3 with an assumed 85% energy savings realized, ramping up to 95% between 2016-2021. Sources are:

- *2013 State Energy Efficiency Scorecard*
- IMT, *Assessment of Energy Efficiency Achievable from Improved Compliance with U.S. Building Energy Codes: 2013–2030*, 9-11, http://www.imt.org/uploads/resources/files/IMT_Report_Code_Compliance_Savings_Potential_FINAL_2013-5-2.pdf.

Average simple payback is the average time (in years) it takes for the cost benefits from construction at a higher code to eclipse the original cost of implementation of a code. Average simple payback for commercial codes is assumed to be six years. Sources are:

- Six-year average simple payback, mid-point between building types and climate zones
- Cost-effectiveness of ASHRAE Standard 90.1-2010 compared to ASHRAE Standard 90.1 2007 Table 5.4, http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22043.pdf.

Cost of administration is the cost of enforcing energy codes using a traditional review and inspection process, based on a cost of $105 per building and the number of new buildings per state, derived from the square feet of commercial building space and a regional average square feet per building. This value assumes no utility program spending, and does not reflect energy savings from retrofits that meet code. Sources are:

- LBNL, *The Cost of Enforcing Building Energy Codes: Phase 2* (not yet published). The incremental cost of enforcing commercial energy codes using a traditional review and inspection process ranges from $50-$160 per building.
- CBECS 2003 for number of buildings and floor space regionally.

COMBINED HEAT AND POWER (CHP) POLICY

CHP is the concurrent generation of electric power and thermal energy. CHP is not a single technology, but rather a particular application of a suite of different technologies, including engines and turbines. Natural gas, coal, biomass, biofuels, and other resources fuel CHP units. Due to the concurrent generation of power and thermal energy, the overall combined electric and thermal efficiency of CHP units can exceed 80%, whereas the current electric generation fleet is only about 35% efficient.

CHP conveys such substantial efficiency benefits because it does more with a single fuel input than typical electric generation. It also is typically located near the point of consumption, so the losses associated with long-distance transmission and distribution are reduced. CHP is most often sized and designed to meet an onsite thermal energy load. The electricity produced concurrently is then either used on site to meet electric demand, or sold to a nearby facility or the grid.

CHP currently represents about 8% of installed U.S. electric generating capacity. Recent additions of CHP capacity have been concentrated in just a few states, including New York, California, Texas, and Connecticut. In 2012 President Obama issued an executive order calling for 40 GW of new CHP capacity in the United States by 2020. With about 80 GW of CHP installed today, the order set an ambitious goal of increasing CHP by 50%.

Current trends in CHP deployment indicate that the president's 2012 goal may be difficult to reach. Few states have policies directly encouraging CHP, and, absent changes in policies and regulation, many utilities do not view CHP as in their economic interest. The states that have seen greater CHP deployment have typically engaged directly with local utilities to identify program structures that can bring in utilities as dedicated partners.

The potential for CHP presented in this paper supposes that more states develop policies that encourage CHP. CHP can represent a significant energy efficiency resource for utilities that are required to meet energy efficiency goals. As more states identify energy efficiency as the lowest-cost energy resource, CHP is well positioned as a premiere efficiency resource that helps keep efficiency portfolio costs down while increasing energy system resilience.

Assumptions and Approaches

CHP CAPACITY POTENTIAL Publicly available ICF data provides technical potential for new CHP in each state for the commercial and industrial sectors.[54] ICF sorted the technical potential by simple payback into three bins: less than a 5-year payback, a 5- to 10-year payback, and more than a 10-year payback. Based on two scenarios in the report, including a "base case" and an "electricity price increase case" with 15% higher electricity prices, we were able to sort the technical potential into five bins. We then assigned an acceptance rate to each bin to translate the economic potential into a likely achievable potential for each state and sector. The bins and associated payback rate are shown in the table B2.

Table B2. Payback bins and acceptance rates

Payback bin	Acceptance rate	Qualitative Description	Detailed Description
Very strong	75%	Less than a 5-year payback	Under 5-year payback in the base case
Strong	50%	Around a 5-year payback	Payback shifted from 5-10 years in base case to under 5 years in electricity price increase case
Moderate	25%	5- to 10-year payback	5-10 year payback regardless of price increase
Weak	10%	Around a 10-year payback	Payback shifted from over 10 years in base case to 5-10 years in electricity price increase case
Minimal	3%	Over a 10-year payback	Over 10-year payback in electricity price increase case

Source: Payback bins adapted from ICF 2013; acceptance rates estimated by ACEEE

This analysis results in a nationwide achievable potential of about 20 GW by 2030, or about half of the president's 2020 goal.[55] Note the analysis does not include any growth in potential CHP opportunities between 2013 and 2030; the CHP accounted for in this study is all technically feasible in 2013. We assume each sector in each state could install a fixed

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[54] ICF International, *The Opportunity for CHP in the United States*, prepared for the American Gas Association, May 2013, http://www.aga.org/Kc/analyses-and-statistics/studies/efficiency_and_environment/Pages/TheOpportunityforCHPintheUnitedStates.aspx.

[55] http://www.whitehouse.gov/the-press-office/2012/08/30/executive-order-accelerating-investment-industrial-energy-efficiency

amount of CHP capacity per year, such that by starting in 2016 it would meet its potential by 2030. However not all of these potential installations occur. For each state, sector, and installation year, we perform a cost-effectiveness screening based on annual electricity and natural gas prices and the operating characteristics of the CHP systems being installed. This screening approximates a benefit-cost ratio (BCR) and screens out investments with a BCR of less than 1. Energy prices are based on the EIA 2013 Annual Energy Outlook. CHP operating characteristics are described in a later section.

ICF ASSUMPTIONS To better understand the technical potential from the ICF study, its key assumptions are listed below:

- Base year used was 2012
- Assumed only "topping" cycle CHP, i.e., no waste heat-to-power
- Looked primarily at high load-factor industrial subsectors, as well as some high and low load-factor commercial and institutional subsectors that might be appropriate for both heating and cooling applications
- Minimum system size considered was 100 kW; maximum system size was 100 MW.[56]
- Facility electric demand was based on models, not actual known load profiles.
- Facility thermal demand was based on CBECS, MECS, and other studies.
- No electricity export was considered. For industrial facilities with high thermal loads, CHP capacity was likely limited by on-site electric demand.
- Existing CHP was subtracted from estimated potential (since the facilities reviewed might or might not already have CHP).
- Electricity and natural gas prices were averaged across state (as opposed to service territory) using 2011 data from EIA.
- No consideration of standby rates/feed-in-tariffs/other production incentives
- Costs include after-treatment emission control and 10% Federal ITC.

Note that these assumptions are built into the data we compiled for our analysis and do not necessarily apply to other parts of our analysis.

CHP OPERATING CHARACTERISTICS The 2013 ICF report also provided a breakdown of typical CHP operating characteristics by size (shown with minor adjustments in table B3 below). Capital and operations and maintenance (O&M) costs were further adjusted to account for avoided purchase and operation of a Boiler MACT-compliant boiler.[57]

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[56] The 100 MW limit was made because the America Gas Association (who commissioned the study) were not interested in large systems that would be unlikely to be supplied by natural gas utilities (large facilities often connect directly to a distribution pipeline). Coincidentally, eliminating larger CHP systems is consistent with the methodology of this ACEEE report, as large CHP systems may not be creditable under 111(d).

[57] See http://www.epa.gov/ttn/atw/boiler/boilerpg.html.

Table B3. CHP operating characteristics by size

Assumed technology	Reciprocating engine		Gas turbine		
Size bin	100 kW - 1MW	1-5 MW	5-20 MW	20-50 MW	50-100 MW
Capacity (kW)	500	3,000	12,500	40,000	80,000
Capital cost ($/kW)	$2,228	$1,710	$1,737	$1,376	$1,430
O&M costs ($/kWh)[1]	$0.02	$0.01	$0.01	$0.01	$0.00
Heat rate (BTU/kWh)	11,199	9,800	11,765	9,220	9,220
Efficiency (%)	79.6	77.7	68.7	71.6	71.6
Economic life (years)	10	15	20	20	20

[1] O&M costs shown here were adjusted to account for higher-than-average capacity utilization for CHP properly sized for local loads. *Source:* Adapted from ICF 2013.

We developed a representative CHP system for each state and sector by taking a weighted average of these data along with a breakdown of each state and sector's technical potential in terms of the size of the potential CHP system (also from ICF).

Calculations

ELECTRICITY SAVINGS AND COSTS FOR CHP CHP does not result in direct electricity end-use savings. Instead, CHP shifts electric load away from centralized power plants to the CHP unit (typically near the point of use) while moderately increasing on-site fuel consumption. Due to the avoided transmission and distribution losses and overall efficiency of cogenerating heat and power, CHP results in primary fuel savings.

Because we assume that CHP systems will be installed instead of upgrading to Boiler MACT-compliant natural gas boilers to meet the thermal load, we can subtract avoided boiler fuel from the total CHP fuel use to obtain what we call the "CHP generation fuel." We use this and the CHP characteristics above to calculate the CHP system's "net heat rate," which is the ratio of the CHP generation fuel to the CHP electric output, measured in mmBtu/MWh. Knowing the total CHP capacity and the CHP net heat rate, we can calculate the amount of electric load shifted away from the power grid and the increased on-site fuel consumption.

Our analysis accounts for the energy savings in two ways. For our macroeconomic analysis, we use the avoided centralized electricity generation and additional on-site fuel use directly. However, in order to be able to compare CHP savings with other end-use energy efficiency policies, we must calculate the effective electricity savings. First we find the net energy savings from CHP, which is the fuel saved at a centralized power plant due to CHP, less the increased on-site fuel consumption to power the CHP system. Then we calculate the amount of end-use electricity savings it would take to achieve the same amount of primary fuel savings at a centralized power plant. We call this the CHP "effective electric savings," and calculate it as shown below:

$$\text{Effective electric savings} = \text{Electric load} \times \left\{1 - \left[\frac{\text{Avg CHP net heat rate}}{\text{Avg power plant heat rate}} \times (1 - \text{T\&D losses})\right]\right\}$$

where:

Electric load = electricity supplied by the CHP being modeled (MWh)

CHP net heat rate = the ratio of the primary energy used by the CHP to generate electricity (*CHP generation fuel*) to the CHP electric output (*Electric load*) (mmBtu/MWh)

Average power plant heat rate = a grid-wide average of the ratio of primary energy input to a power plant to electricity output into the grid (mmBtu/MWh)

T&D losses = energy lost due to inefficiencies in delivering electricity over the power grid, expressed as a percentage of power generation output

CHP COSTS AND FINANCING CHP entails two types of costs (other than fuel costs): installation and O&M.

Installation cost = CHP capacity installed in a given year * Average CHP capital cost

Annual operating cost = Electric load * Average CHP O&M costs

Our analysis assumes that the manufacturing and commercial entities installing CHP pay 15% of the installation cost upfront and finance the rest over a 15-year period. We assume that each year utility programs spend an amount of money equal to about 2% of CHP investments either on sharing best practices and providing technical assistance or on managing a state-level CHP resource standard.

Terms and Data Sources

Electric load is the electricity (MWh) generated by CHP (and hence offset from the grid). It is determined by the CHP capacity potential discussed above and CHP operating hours. We assume new CHP capacity is available only for half of its first year, and that it lasts for the size-dependent economic life in table B2 above. CHP operating hours are estimated at 7,500 hours/year, based on ICF data and ACEEE assumptions. *Source:* "CHP Capacity Potential" section above.

Average CHP net heat rate is the ratio of the amount of energy consumed by a new CHP unit to generate electricity and the *Electric load* (MMBtu/MWh). *Avg CHP net heat rate* is calculated based on the *Avg CHP heat rate*, *Avg CHP efficiency*, and the avoided *Boiler efficiency* as follows:

$$\text{Avg CHP net heat rate} = \text{Avg CHP heat rate} \times \left(1 - \frac{\text{Avg CHP efficiency}}{\text{Boiler efficiency}}\right) + \frac{3.412\ \text{mmBtu/MWh}}{\text{Boiler efficiency}}$$

See the "Electricity Savings and Costs for CHP" section above for *Avg CHP heat rate* and *Avg CHP efficiency.* An assumed boiler efficiency of 80% is based on a Boiler MACT-compliant natural gas noncondensing boiler.[58]

Average power plant heat rate is the rate at which fossil-fueled power plants convert primary fuel energy into electricity delivered to the grid (varying by EPA eGRID sub-region), expressed in mmBtu/MWh. It is based on the "all-fossil" heat rate (calculated from the heat input from non-base-load coal, natural gas, and oil). *Source:* EPA eGRID database, http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

T&D losses: Losses that occur in the transmission of electricity from the point of generation to the point of use. While previous EPA rules have used a 5% T&D line loss factor for CHP, those rules were New Source Performance Standards (NSPS) for larger units which sell some power to the grid. The CHP creditable under 111(d) would sell only a small amount into the grid and would not be affected by any line losses. We use the nationwide average of 6.5% from the EPA eGRID database.

APPLIANCE STANDARDS

Appliance standards set minimum efficiency levels for new appliances, equipment, and lighting. After a state-level standard takes effect for a given product, models that fail to meet the minimum efficiency level can no longer be sold or installed. Thus appliance standards serve to set a floor for the efficiency of the affected products.

Although more than 50 products are currently subject to federal appliance standards, many energy-consuming products are still not subject to these standards, including some products with significant annual electricity consumption such as computers and game consoles. For federally regulated products, states cannot set efficiency standards that are more stringent than the federal minimum standards. However states can set standards for products that are not federally regulated.

States have often taken the lead in establishing efficiency standards. Most of the products now covered by national standards were first subject to state standards. For example, California, New York, and Florida established standards for refrigerators in the 1970s and 80s that were a catalyst for and the basis of the national refrigerator standards established in 1987.

State standards are set by legislatures or state agencies. For example in New York, the state legislature has directed the New York Department of State to develop standards in consultation with the New York State Energy Research and Development Authority (NYSERDA). In California, the California Energy Commission (CEC) develops and adopts new standards. Since 2001, Arizona, California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Washington have each passed state standards.

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[58] See http://www.epa.gov/climateleadership/documents/resources/industrial_boiler_protocol.pdf.

For this analysis, we analyzed potential state standards only for products for which at least one state has already adopted a standard. However the CEC is currently considering energy efficiency standards for an additional nine products including computers, game consoles, fluorescent dimming ballasts, and commercial clothes dryers. Our estimates of the potential electricity savings from state standards are conservative since states might adopt standards for additional products beyond those we have analyzed.

Calculations

National annual electricity savings = Number of installed units * Electricity savings per unit * (1 – Current market share of products meeting new standard)

where the *Number of installed units* is

(a) During ramp-up: Annual shipments * (Years of sales after effective date – 0.5)
(b) After market saturation: Annual shipments * Average product lifetime
(c) After last year of sales: Annual shipments * (Average product lifetime – Years from last year of sales – 0.5)

Last year of sales is 2030. We assume that products are sold throughout the year such that the first year of sales results in one half year of savings.

State annual electricity savings = National annual electricity savings * State allocation

National annual spending (annualized expenditure by sector) = Annual shipments * (1 – Current market share of products meeting new standard) * Incremental cost to meet the new standard

State annual spending (annualized expenditure by sector) = National annual spending * State allocation

We assume no financing is used for these products, so spending is the same as investment each year.

Terms and Data Sources

Annual shipments are the number of units that are shipped each year by manufacturers. Shipments are assumed to remain at current levels for all products. Sources are:

- Association of Pool and Spa Professionals, U.S. Swimming Pool and Hot Tub Market 2013, http://www.apsp.org/files/images/APSP%20statistics%202013.jpg.
- EPA, ENERGY STAR® Unit Shipment and Market Penetration Report Calendar Year 2012 Summary, http://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2012_USD_Summary_Report.pdf?b93e-c12d.
- EPA, ENERGY STAR® Unit Shipment and Market Penetration Report Calendar Year 2011 Summary, http://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2011_USD_Summary_Report.pdf?d7e0-dc8f.

- EPA, WaterSense® High-Efficiency Lavatory Faucet Specification Supporting Statement, 2007 http://www.epa.gov/watersense/docs/faucet_suppstat_final508.pdf.
- Personal communication with manufacturer.

Electricity savings per unit is the difference between the electricity use of a product just meeting the potential standard and that of a typical baseline product. We assume the distribution of efficiency levels above the current baseline and above a future standard are the same, except we assume zero savings for sales that currently meet the potential standards. Sources are:

- California Energy Commission, Update of Appliance Efficiency Regulations, 2004 http://www.energy.ca.gov/reports/2004-11-30_400-04-007F.PDF.
- Pacific Gas and Electric Company, Codes and Standards Enhancement Initiative For PY2004: Title 20 Standards Development: Draft Analysis of Standards Options for Commercial Hot Food Holding Cabinets, http://www.energy.ca.gov/appliances/2003rulemaking/documents/case_studies/CASE_Hot_Food_Holding_Cabs.pdf.
- EPA, Commercial Kitchen Equipment Savings Calculator, 2013, http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CKP.
- EPA, Water Coolers Savings Calculator Purchasing, 2009 http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=WA.
- EPA, WaterSense® High-Efficiency Lavatory Faucet Specification Supporting Statement, 2007, http://www.epa.gov/watersense/docs/faucet_suppstat_final508.pdf.
- Personal communication with manufacturer.

Current market share of products meeting new standard is the portion of shipments that already meet the standard level. Sources are:

- DOE, Compliance Certification Database, 2003 http://www.regulations.doe.gov/certification-data/. Accessed November 7, 2013.
- EPA, ENERGY STAR® Unit Shipment and Market Penetration Report Calendar Year 2012 Summary, http://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2012_USD_Summary_Report.pdf?b93e-c12d.
- EPA, ENERGY STAR® Unit Shipment and Market Penetration Report Calendar Year 2011 Summary, http://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2011_USD_Summary_Report.pdf?d7e0-dc8f.
- Personal communications with industry experts.

Years of sales after effective date is the number of years between the assumed effective date of the standard and the end of the year for which annual savings are being calculated.

Average product lifetime is the average number of years that a product is in use. Sources are:

- California Energy Commission, Update of Appliance Efficiency Regulations, 2004, http://www.energy.ca.gov/reports/2004-11-30_400-04-007F.PDF.
- LBNL, WaterSense Program: Methodology for National Water Savings Analysis Model: Indoor Residential Water Use, 2008, http://eetd.lbl.gov/sites/all/files/lbnl-456e.pdf.
- EPA, Commercial Kitchen Equipment Savings Calculator, 2013, http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CKP.
- EPA, Water Coolers Savings Calculator Purchasing, 2009, http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=WA.

State allocation is the portion of national electricity savings or national spending allocated to an individual state by product. For residential faucets, the state allocation is based on the number of households in a given state compared to the number of households in the United States. For double-ended quartz halogen lamps, hot food holding cabinets, and water dispensers, the state allocation is based on population. For portable electric spas, the state allocation is based on the prevalence of portable electric spas and the average annual temperature in each state. We use average annual temperature to account for greater savings in colder climates than in warmer climates using the following adjustment factor:

$$\frac{(102°\mathrm{F} - \text{average annual temperature of State X } (°\mathrm{F}))}{(102°\mathrm{F} - \text{U.S. weighted average annual temperature } (°\mathrm{F}))}$$

where:

102°F represents the typical water temperature of a portable electric spa

U.S. weighted-average annual temperature is calculated based on the average annual temperature and the prevalence of portable electric spas in each state. Sources are:

- Current Results, Average Annual Temperature for Each U.S. State, 2013 http://www.currentresults.com/Weather/US/average-annual-state-temperatures.php.
- U.S. Census Bureau, State and County QuickFacts, 2013 http://quickfacts.census.gov/qfd/index.html.

Incremental cost to meet the new standard is the difference between the price of a baseline unit and a unit that just meets the standard level. Sources are:

- California Energy Commission, Update of Appliance Efficiency Regulations, 2004, http://www.energy.ca.gov/reports/2004-11-30_400-04-007F.PDF.
- Grainger,Online Catalog, 2013 http://www.grainger.com/Grainger/wwg/start.shtml.

- Pacific Gas and Electric Company, Codes and Standards Enhancement Initiative For PY2004: Title 20 Standards Development: Analysis of Standards Options for Water Dispensers, http://www.energy.ca.gov/appliances/2003rulemaking/documents/case_studies/CASE_Water_Dispensers.pdf.
- Pacific Gas and Electric Company, Codes and Standards Enhancement Initiative For PY2004: Title 20 Standards Development: Draft Analysis of Standards Options for Commercial Hot Food Holding Cabinets, http://www.energy.ca.gov/appliances/2003rulemaking/documents/case_studies/CASE_Hot_Food_Holding_Cabs.pdf.
- EPA, WaterSense® High-Efficiency Lavatory Faucet Specification Supporting Statement, 2007, http://www.epa.gov/watersense/docs/faucet_suppstat_final508.pdf.

Years from last year of sales is the number of years between the last year of sales (2030) and the year for which annual savings are being calculated for years after 2030.

Appendix C. Summary Tables

Table C1. Total energy savings (MWh)

State	Incremental annual energy savings in 2020[1]	Annual energy savings in 2020[2]	Cumulative energy savings by 2020[3]	Incremental annual energy savings in 2030	Annual energy savings in 2030	Cumulative energy savings by 2030
Alabama	1,376,000	4,218,000	10,133,000	1,950,000	18,861,000	137,420,000
Alaska	157,000	553,000	1,418,000	195,000	2,275,000	16,754,000
Arizona	2,180,000	8,835,000	25,192,000	2,886,000	29,151,000	230,170,000
Arkansas	741,000	2,325,000	5,657,000	1,038,000	10,110,000	74,178,000
California	5,615,000	26,441,000	77,362,000	6,866,000	73,696,000	623,899,000
Colorado	1,189,000	4,641,000	12,536,000	1,507,000	15,230,000	120,494,000
Connecticut	699,000	3,279,000	9,541,000	778,000	8,946,000	76,428,000
Delaware	196,000	620,000	1,536,000	265,000	2,660,000	19,550,000
District of Columbia	214,000	654,000	1,575,000	302,000	2,955,000	20,911,000
Florida	3,451,000	11,685,000	28,630,000	5,364,000	54,203,000	388,563,000
Georgia	1,786,000	7,153,000	17,552,000	2,531,000	31,149,000	227,671,000
Hawaii	183,000	1,174,000	3,408,000	179,000	3,423,000	28,497,000
Idaho	261,000	1,734,000	4,711,000	342,000	5,472,000	43,983,000
Illinois	1,839,000	9,901,000	26,244,000	2,281,000	32,886,000	259,712,000
Indiana	1,015,000	6,605,000	17,095,000	1,178,000	22,697,000	177,742,000
Iowa	894,000	3,870,000	10,926,000	1,129,000	11,399,000	94,367,000
Kansas	692,000	2,198,000	5,429,000	907,000	9,338,000	68,759,000
Kentucky	1,427,000	4,459,000	10,782,000	1,953,000	19,742,000	143,648,000
Louisiana	1,584,000	4,940,000	12,096,000	2,126,000	21,668,000	157,763,000
Maine	239,000	1,036,000	2,925,000	289,000	2,998,000	25,011,000

State	Incremental annual energy savings in 2020[1]	Annual energy savings in 2020[2]	Cumulative energy savings by 2020[3]	Incremental annual energy savings in 2030	Annual energy savings in 2030	Cumulative energy savings by 2030
Maryland	1,115,000	5,137,000	14,828,000	1,460,000	14,192,000	120,653,000
Massachusetts	1,380,000	6,377,000	18,690,000	1,528,000	17,704,000	150,398,000
Michigan	1,761,000	8,127,000	23,160,000	2,239,000	22,334,000	190,191,000
Minnesota	1,264,000	5,931,000	17,259,000	1,659,000	16,381,000	139,267,000
Mississippi	835,000	2,666,000	6,551,000	1,138,000	11,457,000	84,118,000
Missouri	1,420,000	4,769,000	12,102,000	1,770,000	17,345,000	133,950,000
Montana	256,000	903,000	2,335,000	320,000	3,137,000	24,452,000
Nebraska	442,000	1,386,000	3,362,000	598,000	6,008,000	44,132,000
Nevada	670,000	2,577,000	6,881,000	863,000	8,532,000	67,378,000
New Hampshire	269,000	1,042,000	2,797,000	279,000	3,330,000	26,735,000
New Jersey	1,606,000	6,402,000	17,253,000	1,816,000	20,147,000	162,399,000
New Mexico	551,000	1,708,000	4,271,000	665,000	6,871,000	50,958,000
New York	4,075,000	18,540,000	53,280,000	3,868,000	52,587,000	442,954,000
North Carolina	2,301,000	7,565,000	19,018,000	3,191,000	30,282,000	226,272,000
North Dakota	228,000	719,000	1,765,000	296,000	3,078,000	22,634,000
Ohio	2,689,000	12,673,000	36,957,000	3,568,000	34,398,000	295,050,000
Oklahoma	952,000	2,973,000	7,248,000	1,333,000	12,930,000	94,797,000
Oregon	976,000	4,025,000	11,200,000	1,283,000	12,422,000	100,800,000
Pennsylvania	2,593,000	11,617,000	32,984,000	3,337,000	32,703,000	276,183,000
Rhode Island	154,000	728,000	2,125,000	187,000	1,951,000	16,803,000
South Carolina	1,381,000	4,445,000	11,005,000	1,862,000	18,566,000	137,355,000
South Dakota	174,000	550,000	1,345,000	241,000	2,356,000	17,376,000

State	Incremental annual energy savings in 2020[1]	Annual energy savings in 2020[2]	Cumulative energy savings by 2020[3]	Incremental annual energy savings in 2030	Annual energy savings in 2030	Cumulative energy savings by 2030
Tennessee	1,914,000	6,392,000	16,153,000	2,487,000	25,086,000	188,671,000
Texas	6,429,000	20,539,000	50,778,000	8,927,000	89,565,000	653,915,000
Utah	630,000	2,497,000	6,817,000	803,000	8,149,000	64,666,000
Vermont	121,000	588,000	1,739,000	138,000	1,558,000	13,495,000
Virginia	1,756,000	5,586,000	13,715,000	2,535,000	24,255,000	177,596,000
Washington	1,681,000	7,154,000	19,840,000	2,271,000	21,445,000	176,061,000
West Virginia	528,000	1,671,000	4,110,000	686,000	7,073,000	52,252,000
Wisconsin	1,340,000	4,918,000	12,911,000	1,547,000	16,484,000	129,985,000
Wyoming	299,000	937,000	2,278,000	388,000	4,172,000	30,154,000
National	**67,528,000**	**267,462,000**	**719,502,000**	**87,351,000**	**925,358,000**	**7,247,173,000**

[1] Energy savings occurring in a single year from only the program measures implemented in the current year. [2] Energy savings occurring in a single year from the combination of program measures implemented in the current year and active savings from measures implemented in prior years. Sum of all incremental annual savings up to the year being calculated less expired savings from previous years after the end of the measure life. [3] Sum of the annual energy savings over a multiyear time frame.

Table C2. Energy savings from annual energy savings target (MWh)

State	Incremental annual energy savings in 2020	Annual energy savings in 2020	Cumulative energy savings by 2020	Incremental annual energy savings in 2030	Annual energy savings in 2030	Cumulative energy savings by 2030
Alabama	1,190,000	3,522,000	8,155,000	1,769,000	16,258,000	117,598,000
Alaska	96,000	280,000	642,000	158,000	1,414,000	9,833,000
Arizona	1,192,000	5,815,000	17,198,000	1,807,000	15,375,000	133,055,000
Arkansas	628,000	1,860,000	4,312,000	928,000	8,459,000	61,579,000
California	4,046,000	19,824,000	58,625,000	5,890,000	52,285,000	453,446,000
Colorado	871,000	3,493,000	9,328,000	1,206,000	10,955,000	88,406,000
Connecticut	439,000	2,166,000	6,411,000	606,000	5,390,000	48,125,000
Delaware	146,000	436,000	1,014,000	211,000	1,940,000	14,240,000
District of Columbia	138,000	421,000	961,000	228,000	1,953,000	13,696,000
Florida	2,651,000	8,580,000	19,876,000	4,383,000	40,128,000	288,814,000
Georgia	1,327,000	5,302,000	12,278,000	2,132,000	24,901,000	178,760,000
Hawaii	93,000	779,000	2,286,000	136,000	2,136,000	18,192,000
Idaho	216,000	1,558,000	4,200,000	295,000	4,808,000	39,010,000
Illinois	1,396,000	8,203,000	21,436,000	1,882,000	26,847,000	213,607,000
Indiana	816,000	5,829,000	14,873,000	994,000	19,901,000	156,426,000
Iowa	697,000	3,181,000	9,014,000	948,000	8,797,000	74,870,000
Kansas	518,000	1,545,000	3,594,000	748,000	6,986,000	50,891,000
Kentucky	1,212,000	3,586,000	8,304,000	1,738,000	16,617,000	119,943,000
Louisiana	1,131,000	3,353,000	7,772,000	1,664,000	15,296,000	111,142,000
Maine	173,000	795,000	2,258,000	229,000	2,116,000	18,333,000
Maryland	919,000	4,322,000	12,445,000	1,295,000	11,404,000	98,937,000

State	Incremental annual energy savings in 2020	Annual energy savings in 2020	Cumulative energy savings by 2020	Incremental annual energy savings in 2030	Annual energy savings in 2030	Cumulative energy savings by 2030
Massachusetts	836,000	4,213,000	12,657,000	1,145,000	10,446,000	93,596,000
Michigan	1,565,000	7,111,000	20,062,000	2,089,000	19,506,000	166,532,000
Minnesota	1,030,000	4,951,000	14,439,000	1,454,000	13,113,000	113,778,000
Mississippi	645,000	1,911,000	4,430,000	955,000	8,692,000	63,258,000
Missouri	1,206,000	3,933,000	9,699,000	1,578,000	14,392,000	111,299,000
Montana	223,000	781,000	1,989,000	291,000	2,689,000	21,054,000
Nebraska	382,000	1,140,000	2,649,000	545,000	5,162,000	37,583,000
Nevada	554,000	2,180,000	5,771,000	734,000	6,850,000	55,303,000
New Hampshire	165,000	611,000	1,590,000	205,000	1,916,000	15,599,000
New Jersey	1,136,000	4,371,000	11,506,000	1,484,000	13,639,000	110,735,000
New Mexico	372,000	1,208,000	2,979,000	493,000	4,593,000	34,786,000
New York	2,029,000	9,972,000	29,363,000	2,838,000	25,332,000	223,925,000
North Carolina	1,898,000	6,002,000	14,543,000	2,700,000	23,831,000	179,271,000
North Dakota	176,000	525,000	1,221,000	251,000	2,376,000	17,299,000
Ohio	2,324,000	11,232,000	32,830,000	3,238,000	29,317,000	256,093,000
Oklahoma	778,000	2,307,000	5,349,000	1,163,000	10,470,000	76,264,000
Oregon	747,000	3,328,000	9,324,000	1,052,000	9,376,000	78,967,000
Pennsylvania	2,244,000	10,241,000	29,013,000	3,041,000	27,895,000	239,028,000
Rhode Island	114,000	558,000	1,640,000	158,000	1,408,000	12,490,000
South Carolina	1,133,000	3,468,000	8,227,000	1,628,000	14,863,000	109,481,000
South Dakota	147,000	439,000	1,022,000	216,000	1,969,000	14,403,000
Tennessee	1,406,000	4,338,000	10,338,000	2,022,000	18,105,000	134,684,000

State	Incremental annual energy savings in 2020	Annual energy savings in 2020	Cumulative energy savings by 2020	Incremental annual energy savings in 2030	Annual energy savings in 2030	Cumulative energy savings by 2030
Texas	4,884,000	14,486,000	33,588,000	7,251,000	65,912,000	479,396,000
Utah	465,000	1,936,000	5,264,000	631,000	5,859,000	47,938,000
Vermont	83,000	421,000	1,266,000	115,000	1,041,000	9,337,000
Virginia	1,432,000	4,243,000	9,835,000	2,218,000	19,605,000	141,652,000
Washington	1,499,000	6,461,000	17,841,000	2,076,000	18,751,000	156,082,000
West Virginia	402,000	1,202,000	2,795,000	566,000	5,343,000	39,220,000
Wisconsin	1,042,000	3,675,000	9,379,000	1,277,000	12,327,000	97,713,000
Wyoming	249,000	735,000	1,701,000	341,000	3,488,000	24,862,000
National	**51,060,000**	**202,832,000**	**537,293,000**	**73,005,000**	**692,228,000**	**5,470,529,000**

Table C3. Energy savings from building codes (MWh)

State	Incremental annual energy savings in 2020	Annual energy savings in 2020	Cumulative energy savings by 2020	Incremental annual energy savings in 2030	Annual energy savings in 2030	Cumulative energy savings by 2030
Alabama	157,000	501,000	1,343,000	181,000	2,306,000	16,206,000
Alaska	21,000	80,000	226,000	24,000	311,000	2,286,000
Arizona	958,000	2,791,000	7,231,000	1,070,000	13,309,000	92,559,000
Arkansas	90,000	317,000	878,000	98,000	1,301,000	9,440,000
California	524,000	1,360,000	3,406,000	538,000	6,769,000	46,818,000
Colorado	280,000	905,000	2,432,000	280,000	3,705,000	26,930,000
Connecticut	78,000	242,000	640,000	76,000	1,010,000	7,313,000
Delaware	49,000	164,000	450,000	53,000	693,000	4,982,000
District of Columbia	73,000	209,000	535,000	74,000	952,000	6,724,000
Florida	530,000	1,610,000	4,230,000	915,000	10,270,000	66,118,000
Georgia	323,000	1,096,000	2,987,000	399,000	5,008,000	35,161,000
Hawaii	27,000	91,000	252,000	36,000	445,000	3,077,000
Idaho	42,000	141,000	386,000	47,000	616,000	4,398,000
Illinois	328,000	990,000	2,596,000	332,000	4,304,000	30,748,000
Indiana	157,000	495,000	1,317,000	166,000	2,167,000	15,486,000
Iowa	185,000	590,000	1,581,000	181,000	2,418,000	17,606,000
Kansas	147,000	486,000	1,319,000	144,000	1,942,000	14,242,000
Kentucky	134,000	445,000	1,207,000	147,000	1,929,000	13,805,000
Louisiana	333,000	979,000	2,546,000	364,000	4,612,000	32,246,000
Maine	61,000	200,000	526,000	60,000	805,000	5,885,000
Maryland	161,000	573,000	1,599,000	165,000	2,276,000	16,764,000

State	Incremental annual energy savings in 2020	Annual energy savings in 2020	Cumulative energy savings by 2020	Incremental annual energy savings in 2030	Annual energy savings in 2030	Cumulative energy savings by 2030
Massachusetts	265,000	814,000	2,155,000	252,000	3,372,000	24,495,000
Michigan	159,000	520,000	1,400,000	150,000	2,054,000	15,148,000
Minnesota	169,000	608,000	1,683,000	167,000	2,307,000	17,174,000
Mississippi	129,000	433,000	1,170,000	145,000	1,875,000	13,386,000
Missouri	191,000	644,000	1,755,000	193,000	2,592,000	18,955,000
Montana	30,000	92,000	242,000	30,000	392,000	2,820,000
Nebraska	40,000	133,000	360,000	43,000	560,000	4,032,000
Nevada	105,000	309,000	812,000	129,000	1,516,000	10,368,000
New Hampshire	44,000	139,000	374,000	43,000	570,000	4,152,000
New Jersey	149,000	454,000	1,199,000	150,000	1,965,000	14,076,000
New Mexico	168,000	416,000	1,021,000	167,000	2,097,000	14,471,000
New York	647,000	1,990,000	5,268,000	618,000	8,253,000	59,927,000
North Carolina	367,000	1,257,000	3,437,000	490,000	5,996,000	41,496,000
North Dakota	46,000	156,000	426,000	46,000	615,000	4,524,000
Ohio	279,000	885,000	2,364,000	288,000	3,782,000	27,181,000
Oklahoma	162,000	555,000	1,520,000	170,000	2,263,000	16,462,000
Oregon	223,000	612,000	1,566,000	232,000	2,926,000	20,411,000
Pennsylvania	291,000	925,000	2,472,000	296,000	3,912,000	28,209,000
Rhode Island	18,000	55,000	147,000	17,000	227,000	1,651,000
South Carolina	190,000	645,000	1,765,000	235,000	2,937,000	20,618,000
South Dakota	23,000	80,000	218,000	25,000	332,000	2,396,000
Tennessee	427,000	1,439,000	3,901,000	464,000	6,155,000	44,238,000

State	Incremental annual energy savings in 2020	Annual energy savings in 2020	Cumulative energy savings by 2020	Incremental annual energy savings in 2030	Annual energy savings in 2030	Cumulative energy savings by 2030
Texas	1,225,000	4,232,000	11,634,000	1,489,000	18,934,000	133,768,000
Utah	161,000	489,000	1,288,000	172,000	2,201,000	15,570,000
Vermont	10,000	33,000	90,000	10,000	129,000	953,000
Virginia	248,000	878,000	2,431,000	272,000	3,641,000	26,408,000
Washington	171,000	544,000	1,453,000	195,000	2,484,000	17,475,000
West Virginia	102,000	336,000	906,000	102,000	1,374,000	10,008,000
Wisconsin	164,000	558,000	1,520,000	161,000	2,198,000	16,193,000
Wyoming	48,000	163,000	442,000	47,000	639,000	4,711,000
National	**10,905,000**	**34,659,000**	**92,709,000**	**12,146,000**	**155,443,000**	**1,100,070,000**

Table C4. Energy savings from combined heat and power (MWh)

State	Incremental annual energy savings in 2020	Annual energy savings in 2020	Cumulative energy savings by 2020	Incremental annual energy savings in 2030	Annual energy savings in 2030	Cumulative energy savings by 2030
Alabama	20,000	92,000	255,000	0	153,000	1,888,000
Alaska	39,000	177,000	491,000	14,000	532,000	4,367,000
Arizona	20,000	89,000	248,000	9,000	271,000	2,212,000
Arkansas	19,000	85,000	235,000	12,000	262,000	2,103,000
California	990,000	4,457,000	12,381,000	438,000	13,533,000	110,322,000
Colorado	29,000	132,000	367,000	20,000	413,000	3,289,000
Connecticut	177,000	794,000	2,207,000	96,000	2,438,000	19,698,000
Delaware	0	0	0	0	0	0
District of Columbia	2,000	11,000	30,000	0	31,000	263,000
Florida	240,000	1,081,000	3,001,000	67,000	3,221,000	26,666,000
Georgia	121,000	544,000	1,511,000	0	946,000	10,228,000
Hawaii	61,000	274,000	760,000	7,000	801,000	6,736,000
Idaho	0	0	0	0	0	0
Illinois	96,000	433,000	1,203,000	66,000	1,351,000	10,767,000
Indiana	31,000	140,000	390,000	18,000	432,000	3,482,000
Iowa	7,000	32,000	89,000	0	92,000	783,000
Kansas	23,000	105,000	290,000	15,000	324,000	2,597,000
Kentucky	74,000	334,000	927,000	67,000	1,065,000	8,332,000
Louisiana	113,000	511,000	1,419,000	99,000	1,624,000	12,738,000
Maine	3,000	12,000	33,000	0	34,000	293,000
Maryland	26,000	117,000	324,000	0	337,000	2,868,000

State	Incremental annual energy savings in 2020	Annual energy savings in 2020	Cumulative energy savings by 2020	Incremental annual energy savings in 2030	Annual energy savings in 2030	Cumulative energy savings by 2030
Massachusetts	269,000	1,209,000	3,359,000	131,000	3,690,000	29,956,000
Michigan	22,000	282,000	915,000	0	471,000	4,912,000
Minnesota	57,000	256,000	712,000	38,000	797,000	6,372,000
Mississippi	57,000	258,000	717,000	38,000	802,000	6,412,000
Missouri	14,000	62,000	172,000	0	179,000	1,519,000
Montana	2,000	9,000	24,000	0	25,000	212,000
Nebraska	17,000	75,000	207,000	10,000	231,000	1,855,000
Nevada	6,000	29,000	80,000	0	84,000	711,000
New Hampshire	58,000	262,000	728,000	31,000	804,000	6,499,000
New Jersey	308,000	1,387,000	3,853,000	181,000	4,278,000	34,424,000
New Mexico	8,000	38,000	106,000	5,000	118,000	948,000
New York	1,370,000	6,163,000	17,120,000	412,000	18,423,000	152,164,000
North Carolina	22,000	98,000	271,000	0	163,000	2,008,000
North Dakota	5,000	23,000	63,000	0	65,000	556,000
Ohio	68,000	307,000	852,000	42,000	949,000	7,613,000
Oklahoma	6,000	29,000	80,000	0	83,000	709,000
Oregon	0	0	0	0	0	0
Pennsylvania	39,000	174,000	485,000	0	504,000	4,284,000
Rhode Island	20,000	92,000	255,000	13,000	284,000	2,281,000
South Carolina	51,000	231,000	641,000	0	624,000	5,562,000
South Dakota	2,000	12,000	39,000	0	31,000	276,000
Tennessee	71,000	477,000	1,406,000	0	632,000	7,432,000

State	Incremental annual energy savings in 2020	Annual energy savings in 2020	Cumulative energy savings by 2020	Incremental annual energy savings in 2030	Annual energy savings in 2030	Cumulative energy savings by 2030
Texas	283,000	1,273,000	3,536,000	187,000	3,959,000	31,636,000
Utah	0	12,000	43,000	0	6,000	156,000
Vermont	27,000	120,000	333,000	14,000	368,000	2,972,000
Virginia	65,000	291,000	808,000	46,000	766,000	6,624,000
Washington	0	0	0	0	0	0
West Virginia	21,000	94,000	262,000	18,000	299,000	2,351,000
Wisconsin	125,000	562,000	1,560,000	109,000	1,786,000	14,010,000
Wyoming	1,000	26,000	89,000	0	27,000	372,000
National	**5,087,000**	**23,270,000**	**64,878,000**	**2,201,000**	**68,309,000**	**564,459,000**

Table C5. Energy savings from equipment standards

State	Incremental annual energy savings in 2020 (MWh)	Annual energy savings in 2020 (MWh)	Cumulative energy savings by 2020 (MWh)	Incremental annual energy savings in 2030 (MWh)	Annual energy savings in 2030 (MWh)	Cumulative energy savings by 2030 (MWh)
Alabama	7,000	103,000	379,000	0	145,000	1,729,000
Alaska	1,000	16,000	58,000	0	19,000	267,000
Arizona	10,000	140,000	514,000	0	196,000	2,344,000
Arkansas	5,000	63,000	232,000	0	88,000	1,056,000
California	55,000	800,000	2,950,000	0	1,110,000	13,313,000
Colorado	8,000	111,000	409,000	0	157,000	1,868,000
Connecticut	6,000	77,000	283,000	0	108,000	1,292,000
Delaware	1,000	20,000	72,000	0	27,000	328,000
District of Columbia	1,000	14,000	50,000	0	19,000	227,000
Florida	30,000	415,000	1,523,000	0	584,000	6,965,000
Georgia	15,000	211,000	775,000	0	294,000	3,521,000
Hawaii	2,000	30,000	109,000	0	41,000	493,000
Idaho	2,000	34,000	126,000	0	48,000	574,000
Illinois	19,000	274,000	1,009,000	0	384,000	4,590,000
Indiana	10,000	140,000	514,000	0	197,000	2,348,000
Iowa	5,000	66,000	242,000	0	93,000	1,109,000
Kansas	4,000	62,000	226,000	0	86,000	1,030,000
Kentucky	7,000	94,000	344,000	0	131,000	1,569,000
Louisiana	7,000	98,000	360,000	0	137,000	1,637,000
Maine	2,000	30,000	107,000	0	42,000	501,000
Maryland	9,000	125,000	459,000	0	174,000	2,084,000

State	Incremental annual energy savings in 2020 (MWh)	Annual energy savings in 2020 (MWh)	Cumulative energy savings by 2020 (MWh)	Incremental annual energy savings in 2030 (MWh)	Annual energy savings in 2030 (MWh)	Cumulative energy savings by 2030 (MWh)
Massachusetts	10,000	141,000	518,000	0	196,000	2,351,000
Michigan	16,000	214,000	784,000	0	302,000	3,599,000
Minnesota	8,000	116,000	425,000	0	163,000	1,943,000
Mississippi	4,000	64,000	234,000	0	89,000	1,063,000
Missouri	9,000	130,000	476,000	0	183,000	2,177,000
Montana	2,000	22,000	80,000	0	31,000	366,000
Nebraska	3,000	40,000	146,000	0	55,000	663,000
Nevada	4,000	59,000	218,000	0	83,000	995,000
New Hampshire	2,000	29,000	105,000	0	41,000	485,000
New Jersey	13,000	189,000	695,000	0	265,000	3,165,000
New Mexico	3,000	45,000	165,000	0	63,000	753,000
New York	29,000	415,000	1,529,000	0	580,000	6,938,000
North Carolina	15,000	209,000	767,000	0	293,000	3,497,000
North Dakota	1,000	15,000	55,000	0	21,000	254,000
Ohio	18,000	248,000	910,000	0	349,000	4,163,000
Oklahoma	6,000	81,000	299,000	0	114,000	1,362,000
Oregon	6,000	85,000	309,000	0	119,000	1,422,000
Pennsylvania	20,000	277,000	1,014,000	0	392,000	4,661,000
Rhode Island	2,000	23,000	83,000	0	32,000	381,000
South Carolina	7,000	101,000	371,000	0	142,000	1,694,000
South Dakota	1,000	18,000	66,000	0	25,000	301,000
Tennessee	10,000	138,000	508,000	0	194,000	2,318,000

State	Incremental annual energy savings in 2020 (MWh)	Annual energy savings in 2020 (MWh)	Cumulative energy savings by 2020 (MWh)	Incremental annual energy savings in 2030 (MWh)	Annual energy savings in 2030 (MWh)	Cumulative energy savings by 2030 (MWh)
Texas	38,000	548,000	2,020,000	0	760,000	9,115,000
Utah	4,000	60,000	222,000	0	84,000	1,002,000
Vermont	1,000	14,000	50,000	0	20,000	233,000
Virginia	12,000	174,000	641,000	0	244,000	2,912,000
Washington	11,000	149,000	546,000	0	210,000	2,504,000
West Virginia	3,000	40,000	147,000	0	57,000	674,000
Wisconsin	9,000	123,000	452,000	0	173,000	2,068,000
Wyoming	1,000	12,000	46,000	0	18,000	210,000
National	**476,000**	**6,702,000**	**24,622,000**	**0**	**9,378,000**	**112,115,000**

Table C6. Total cost and savings, all four policies (2011$)

State	Average cost per MWh saved	Cumulative cost of energy savings by 2030 (millions)	Cumulative avoided electricity purchases by 2030 (millions)	Cost of energy savings in 2030 (millions)	Avoided electricity purchases in 2030 (millions)	Net cost of energy savings 2016-2030 (millions)	Net cost of energy savings in 2030 (millions)
Alabama	$49.95	$6,900	$10,700	$900	$1,500	-$3,800	-$600
Alaska	$54.39	$900	$2,900	$100	$400	-$2,000	-$300
Arizona	$47.36	$10,900	$22,400	$1,400	$3,000	-$11,500	-$1,600
Arkansas	$50.74	$3,800	$5,900	$500	$800	-$2,100	-$300
California	$56.99	$35,600	$88,700	$4,200	$10,400	-$53,100	-$6,200
Colorado	$58.37	$7,000	$10,400	$900	$1,400	-$3,400	-$500
Connecticut	$54.55	$4,200	$13,500	$500	$1,700	-$9,300	-$1,200
Delaware	$48.59	$900	$1,800	$100	$200	-$900	-$100
District of Columbia	$46.44	$1,000	$2,300	$100	$300	-$1,300	-$200
Florida	$50.75	$19,700	$40,400	$2,800	$5,700	-$20,700	-$2,900
Georgia	$49.54	$11,300	$20,200	$1,500	$2,700	-$8,900	-$1,200
Hawaii	$61.67	$1,800	$10,300	$200	$1,200	-$8,500	-$1,000
Idaho	$53.16	$2,300	$2,600	$300	$300	-$300	$0
Illinois	$51.42	$13,400	$24,500	$1,700	$3,100	-$11,100	-$1,400
Indiana	$51.14	$9,100	$15,700	$1,200	$2,000	-$6,600	-$800
Iowa	$48.78	$4,600	$6,300	$600	$800	-$1,700	-$200
Kansas	$53.40	$3,700	$5,800	$500	$800	-$2,100	-$300
Kentucky	$46.57	$6,700	$11,500	$900	$1,600	-$4,800	-$700
Louisiana	$47.85	$7,500	$13,700	$1,000	$2,000	-$6,200	-$1,000
Maine	$60.37	$1,500	$2,700	$200	$300	-$1,200	-$100

State	Average cost per MWh saved	Cumulative cost of energy savings by 2030 (millions)	Cumulative avoided electricity purchases by 2030 (millions)	Cost of energy savings in 2030 (millions)	Avoided electricity purchases in 2030 (millions)	Net cost of energy savings 2016-2030 (millions)	Net cost of energy savings in 2030 (millions)
Maryland	$47.72	$5,800	$11,800	$700	$1,400	-$6,000	-$700
Massachusetts	$55.52	$8,300	$22,600	$1,000	$2,800	-$14,300	-$1,800
Michigan	$50.84	$9,700	$16,800	$1,100	$2,000	-$7,100	-$900
Minnesota	$56.11	$7,800	$11,000	$900	$1,300	-$3,200	-$400
Mississippi	$51.18	$4,300	$8,200	$600	$1,200	-$3,900	-$600
Missouri	$52.23	$7,000	$10,400	$900	$1,400	-$3,400	-$500
Montana	$51.24	$1,300	$1,800	$200	$200	-$500	$0
Nebraska	$50.96	$2,200	$3,100	$300	$400	-$900	-$100
Nevada	$55.51	$3,700	$5,400	$500	$700	-$1,700	-$200
New Hampshire	$59.62	$1,600	$4,200	$200	$500	-$2,600	-$300
New Jersey	$52.53	$8,500	$21,700	$1,100	$2,700	-$13,200	-$1,600
New Mexico	$44.47	$2,300	$4,400	$300	$600	-$2,100	-$300
New York	$54.03	$23,900	$76,600	$2,800	$9,400	-$52,700	-$6,600
North Carolina	$47.55	$10,800	$18,400	$1,400	$2,500	-$7,600	-$1,100
North Dakota	$49.72	$1,100	$1,500	$200	$200	-$400	$0
Ohio	$50.46	$14,900	$27,700	$1,700	$3,300	-$12,800	-$1,600
Oklahoma	$49.80	$4,700	$6,900	$600	$1,000	-$2,200	-$400
Oregon	$47.88	$4,800	$6,900	$600	$900	-$2,100	-$300
Pennsylvania	$49.66	$13,700	$22,000	$1,600	$2,700	-$8,300	-$1,100
Rhode Island	$53.89	$900	$2,100	$100	$300	-$1,200	-$200
South Carolina	$48.99	$6,700	$11,600	$900	$1,600	-$4,900	-$700

State	Average cost per MWh saved	Cumulative cost of energy savings by 2030 (millions)	Cumulative avoided electricity purchases by 2030 (millions)	Cost of energy savings in 2030 (millions)	Avoided electricity purchases in 2030 (millions)	Net cost of energy savings 2016-2030 (millions)	Net cost of energy savings in 2030 (millions)
South Dakota	$59.07	$1,000	$1,200	$100	$200	-$200	-$100
Tennessee	$45.34	$8,600	$13,800	$1,100	$1,900	-$5,200	-$800
Texas	$47.86	$31,300	$58,200	$4,300	$8,800	-$26,900	-$4,500
Utah	$52.66	$3,400	$4,000	$400	$500	-$600	-$100
Vermont	$57.54	$800	$1,900	$100	$200	-$1,100	-$100
Virginia	$48.20	$8,600	$14,800	$1,200	$2,000	-$6,200	-$800
Washington	$51.06	$9,000	$10,000	$1,100	$1,300	-$1,000	-$200
West Virginia	$46.18	$2,400	$4,400	$300	$600	-$2,000	-$300
Wisconsin	$58.76	$7,600	$12,300	$1,000	$1,600	-$4,700	-$600
Wyoming	$46.71	$1,400	$1,800	$200	$300	-$400	-$100
National	**$50.68**	**$367,300**	**$730,000**	**$46,900**	**$95,100**	**-$362,700**	**-$48,200**

Table C7. Net job impacts, all four policies

State	2020	2030
Alabama	3,900	9,400
Alaska	400	900
Arizona	11,000	23,300
Arkansas	1,800	4,800
California	30,600	53,000
Colorado	4,900	10,200
Connecticut	3,600	6,500
Delaware	700	1,700
District of Columbia	600	1,400
Florida	13,300	38,400
Georgia	7,300	18,500
Hawaii	2,000	3,800
Idaho	1,300	3,100
Illinois	8,800	19,800
Indiana	5,500	11,900
Iowa	4,000	5,900
Kansas	2,500	5,400
Kentucky	3,600	8,700
Louisiana	5,000	11,500
Maine	1,400	2,800
Maryland	3,700	7,900
Massachusetts	7,600	12,600
Michigan	6,600	13,800
Minnesota	6,200	9,700
Mississippi	2,900	7,000
Missouri	4,700	10,600
Montana	800	1,800
Nebraska	1,300	3,300
Nevada	2,100	5,100
New Hampshire	1,400	2,700
New Jersey	6,300	13,300
New Mexico	1,800	3,800
New York	22,800	40,100
North Carolina	7,700	18,700
North Dakota	700	1,400
Ohio	10,600	23,000
Oklahoma	2,400	6,500
Oregon	4,000	7,000
Pennsylvania	7,900	16,600
Rhode Island	700	1,300
South Carolina	4,600	10,800
South Dakota	600	1,500
Tennessee	6,200	13,500
Texas	19,800	55,300
Utah	2,700	5,900
Vermont	700	1,200
Virginia	5,200	13,000
Washington	4,300	10,200
West Virginia	1,300	2,700
Wisconsin	6,400	9,900
Wyoming	600	1,300
National	**288,900**	**611,200**