The Greatest Energy Story You Haven't Heard:

How Investing in Energy Efficiency Changed the US Power Sector and Gave Us a Tool to Tackle Climate Change

ACEEE
American Council for an Energy-Efficient Economy

The energy efficiency success story

An invisible resource is working quietly behind the scenes to provide American families and businesses with the power necessary to live and work. This resource lowers harmful pollution, creates US jobs, reduces energy burdens for those most in need, and strengthens community resilience. It also improves the bottom line for business, returns at least double its investment, and saves American households, on average, $840 dollars a year. Energy efficiency has become the nation's third-largest electricity resource. With increased support it could become the largest—and one of the world's core strategies to tackle climate change.

What is energy efficiency?

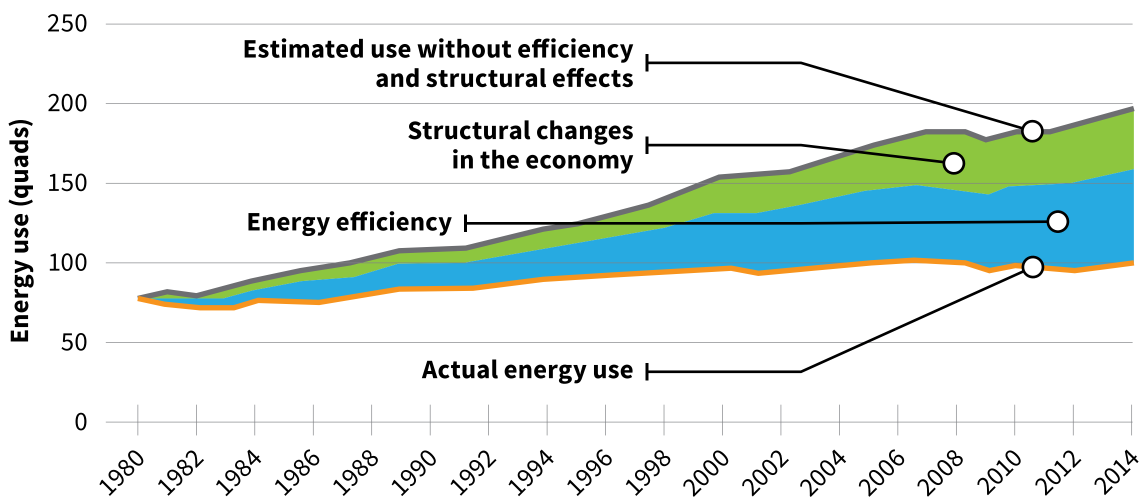
Energy efficiency is the use of less energy to provide the same or better products, services, or amenities. Increasing efficiency allows more control over energy use, lowers costs, and provides multiple benefits for households, businesses, and the environment. For example, adding insulation to a home improves both its efficiency and its comfort. Increasing the efficiency of a manufacturing process can enhance the competitiveness of the plant. And by lowering energy use, all forms of energy efficiency cut pollution.

For the past 40 years, energy efficiency has been a quiet success story in America's energy sector. As the 1973 oil crisis put pressure on energy security and as prices spiked, consumers looked for ways to conserve energy and reduce environmental impacts. In response, a diverse group of scientists, analysts, and policymakers began to develop strategies to reduce energy waste and use less energy to deliver the same or better services to consumers and businesses. Today, energy-efficient technologies, policies, and programs impact everyone and have greatly influenced utilities, building designers, industrial planners, and manufacturers. The result has been an unqualified success story, both economically and environmentally, although one often unseen by the public.

The US economy grew without runaway energy use

One way to see energy efficiency's effects is to look at the relationship between energy use and gross domestic product (GDP). From 1980 to 2014, our GDP increased by 149% while energy use in the United States increased by just 26%, from 78 quads (or a quadrillion Btus) to 98 quads, as shown in figure 1.[1]

Figure 1. US energy use: actual use and estimated use without efficiency and structural changes in the economy.

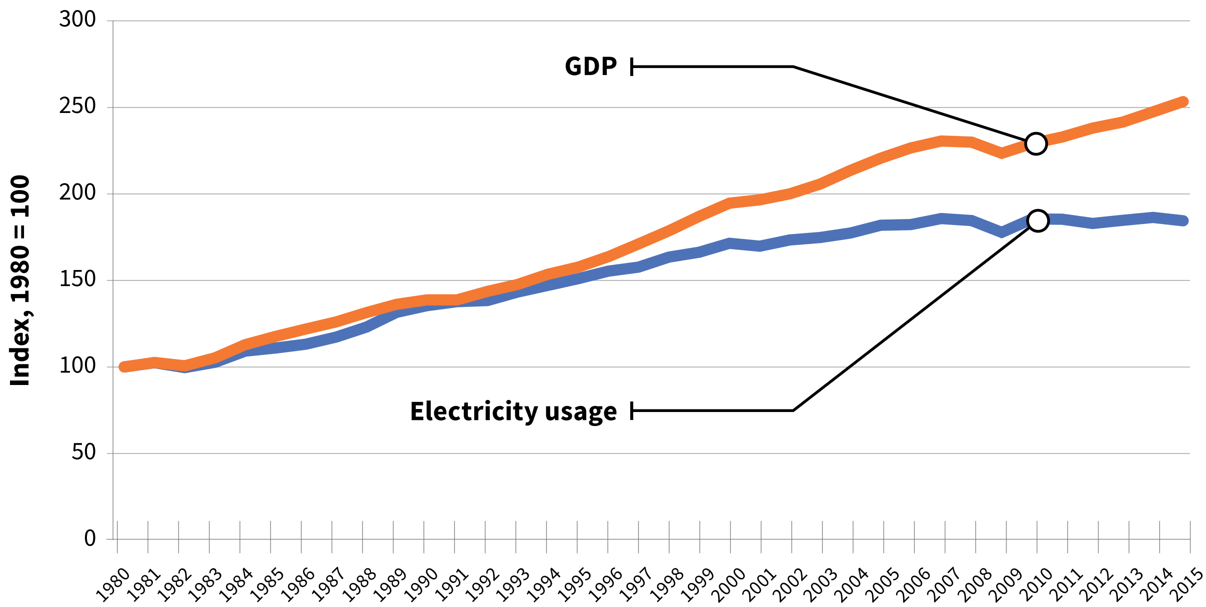


Source: See page 17 for this and other figure sources.

While the improvement in energy used per unit of GDP was partly due to structural changes in the economy, such as a shift away from some energy-intensive sectors like heavy manufacturing to service industries, energy efficiency was an important contributor to this trend.[2] If we continued using energy at the same rate per unit of GDP, in 2014 the United States would have used 195 quads. When we factor out structural change, we are left with efficiency-related savings of about 58 quads, which is more than half of today's energy consumption.

In the electricity sector, which is the focus of this paper, we see another sign of major progress. Total demand for electricity has flattened in recent years even as the economy, measured by GDP, has grown (see figure 2).[3] While this trend is driven by many factors, such as annual differences in weather and changes in the structure of the economy, a large part is due to energy efficiency policies and programs that have helped lead to more energy-efficient products and services. Stronger energy efficiency policies and programs have become even more widespread in the last decade.

Figure 2. US growth trends in electricity usage (TWh) versus gross domestic product (GDP)



Energy efficiency is a major building block in international and US climate plans

By saving energy and cutting pollution, energy efficiency also has a critical role to play in climate change mitigation. In the United States, the electricity sector is currently the largest emitter of greenhouse gases (GHG), contributing 30.5% of the total, as shown in figure 3.[4] The transportation sector is the second-largest emitter, followed by industry, commercial and residential fuel use, and agriculture. Energy efficiency has made significant strides in all of these sectors and has the potential to contribute significantly more toward US and international emissions targets.

For example, the International Energy Agency (IEA) has modeled a scenario in which the global increase in temperature is limited to 2°C. In this model, energy efficiency from all sectors accounts for nearly half of all greenhouse gas emissions reductions, as shown in figure 4.[5] And in the United States, ACEEE has found that energy efficiency policies can play a major role in each state's compliance plan for the Environmental Protection Agency's Clean Power Plan, which is aimed at reducing greenhouse gas emissions in the electricity sector to limit climate change.[6] Most states could meet at least 25% of their emissions reduction requirements through efficiency policies and the resulting investments, and many could achieve 100%.[7]

Figure 3. Total US greenhouse gas emissions by economic sector in 2014

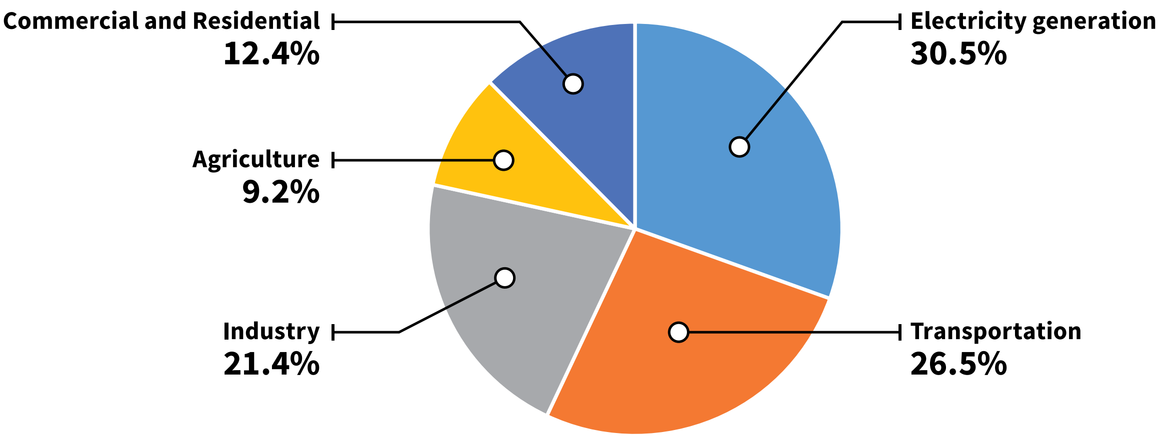
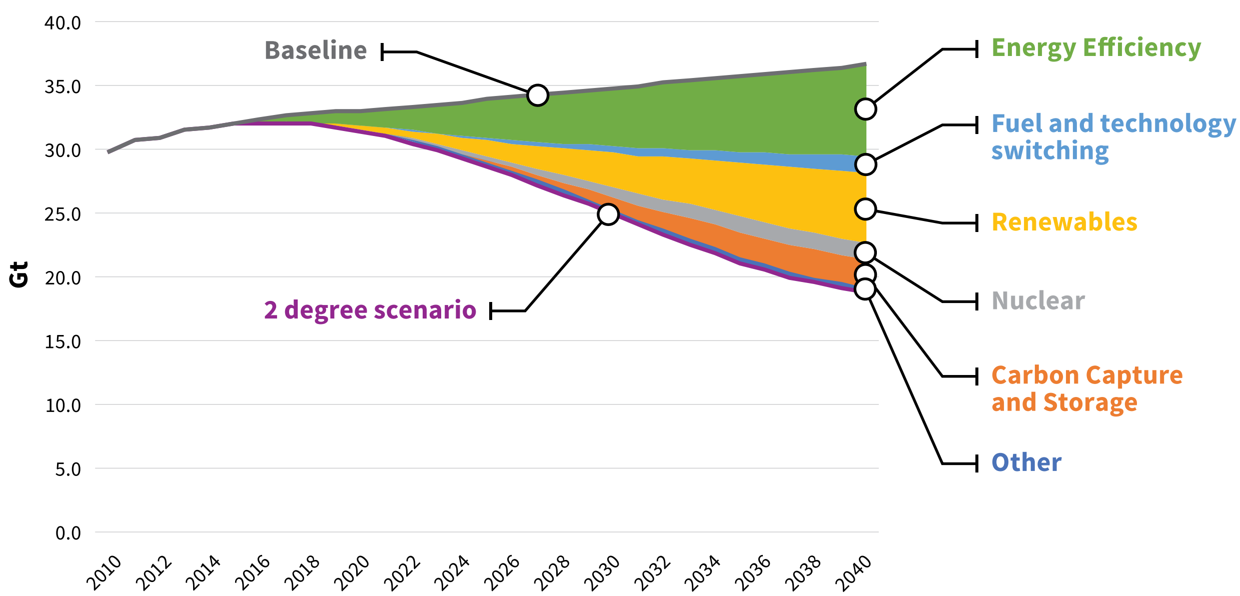


Figure 4. IEA *Global Energy Outlook* emissions scenario with temperature increase limited to 2 degrees



Other Sectors

This paper focuses on the story of reducing energy waste in the electricity sector (including electricity use in the industrial sector) through energy efficiency.[8] However, many energy trends and efficiency opportunities have parallel stories in other sectors. For example, the transportation sector could potentially reach zero emissions by 2050, with more than half of the reductions coming from energy efficiency, including both vehicle and transportation system efficiency.[9] As the electric power grid becomes cleaner, moving the transportation sector to electricity will mean lower emissions and even more benefits across multiple sectors of the economy.[10] In the commercial and residential buildings sector, large opportunities exist for improved space heating and water heating, which can save both fuel and water.

Energy efficiency is now the third-largest electricity resource in the United States

Utilities can meet electricity demand by generating power, or they can encourage efficient technologies as a way to reduce their customers' energy waste while providing the same level of service. In this way, energy efficiency is a resource similar to power plants, wind turbines, or solar panels. In many areas of the country, electric utility planners for years have been relying on energy efficiency to keep the lights on.[11] This is because efficiency, when compared with other sources like coal, natural gas, and renewables, is generally our least expensive energy option. The Northwest Power and Conservation Council, a national pioneer in planning and implementing energy efficiency as a resource, estimates that energy efficiency is the second-largest electricity resource in the Pacific Northwest, second only to hydropower, and is the single largest contributor to meeting the region's future electricity needs.[12]

Today in the electric power sector, ACEEE estimates that energy efficiency—through a select group of policies and programs implemented since 1990—is the nation's third-largest electricity resource, greater than the contribution of nuclear power (see figure 5).[13] Investments in energy efficiency have paid off, saving customers money, reducing pollution, advancing cutting-edge technology, and creating jobs. Without the energy efficiency investments we have made since 1990, we would need the equivalent of 313 additional large power plants today to meet the country's energy needs.[14] This is equivalent to three times the coal plant capacity in Germany, or nearly half of the existing coal plant capacity in the United States as of 2012.[15]

Measuring energy savings

There are inherent challenges in measuring energy efficiency's effects because it requires us to compare actual energy use against what would have been used if energy efficiency improvements had not been made. This is much different from how we measure resources like wind power, where we can quantify actual output from wind turbines. However, the powerful effects of energy efficiency can be seen in a number of ways. The United States has decades of experience with evaluation, measurement, and verification (EM&V), a process that confirms energy savings and guides future energy efficiency investment decisions. Recent advances in data availability and analytics are making this task easier, for example through automated and real-time energy efficiency measurement.[17] These new opportunities, combined with best practices and ongoing national coordination efforts to harmonize energy efficiency protocols, are bringing a new level of insight to the task of measuring energy efficiency.[18]

Figure 5. US electricity generation and savings from energy efficiency in 2015

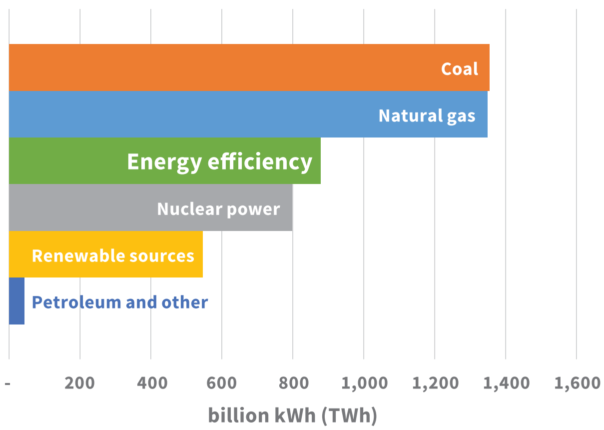
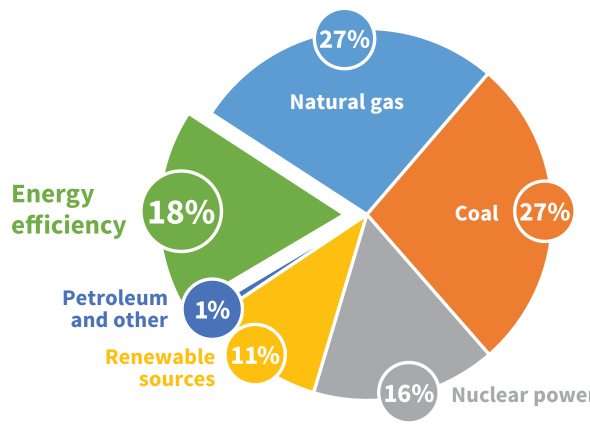


Figure 6. Share of US electricity generation by resource in 2015



If we considered energy efficiency as a segment of our nation's electricity resource "pie," based on ACEEE estimates, it would count as 18% of total generation in 2015 (see figure 6).

In recent years efficiency has rapidly grown as a resource, and it has the potential to grow much more. We already have experience implementing federal, state, and local policies that are proven to work. If we increase our use of these policies, efficiency has the potential to become our nation's largest electricity resource by 2030, providing one-third of total expected electricity generation needs (see figures 7 and 8).[16] These additional energy savings by 2030 would avoid the need for electrical capacity equivalent to 487 power plants. Combined with past gains since 1990, by 2030 energy efficiency could amount to the output of 800 power plants.

Figure 7. Projected US electricity generation and savings from energy efficiency in 2030, with increased energy efficiency policies

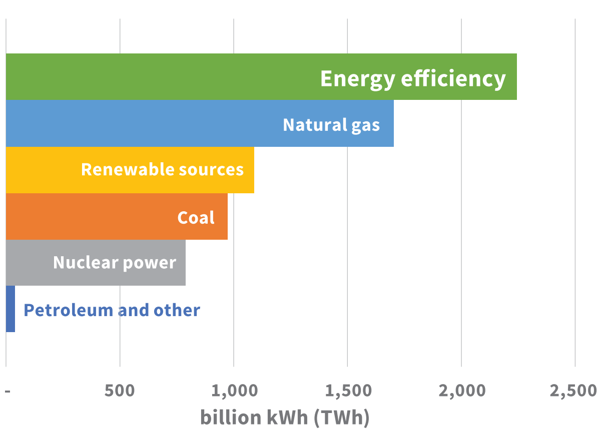
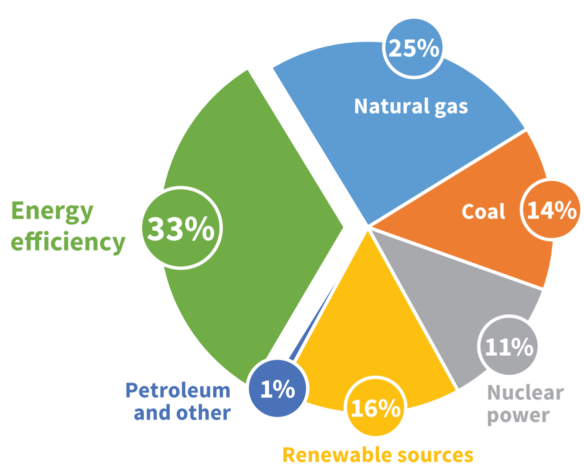


Figure 8. Share of US electricity generation by resource in 2030, with increased energy efficiency policies



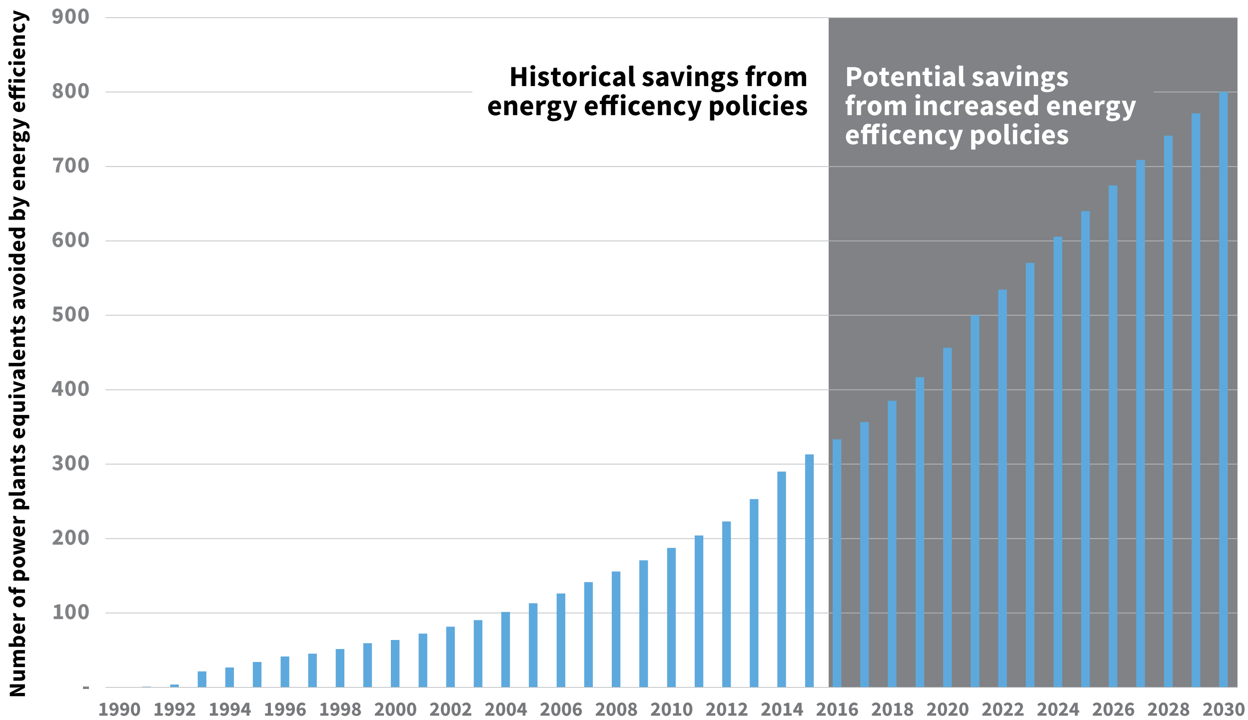
Why should we keep investing in energy efficiency? The benefits are enormous.

Energy efficiency delivers multiple benefits to our economy. It reduces pollution, saves money on household and business energy bills, and improves equity, health, and comfort. It also increases community and grid resilience, creates jobs, and expands economic development.[19]

Decreases greenhouse gas emissions and other forms of pollution

It has often been said that the cleanest kilowatt-hour is the one never used. Because it lowers electricity use, energy efficiency avoids emissions of greenhouse gases and other harmful pollutants, including nitrogen oxides, sulfur dioxide, and particulates. As described earlier, ACEEE estimates that efficiency has avoided the need to build the equivalent of 313 large power plants since 1990 (see figure 9), reducing annual carbon dioxide emissions, a major contributor to climate change, by 490 million tons in 2015. And we can do much more. With a well-designed set of policies, efficiency can avoid a total of 800 power plants by 2030, as figure 9 illustrates. These savings would mean 1 billion tons fewer annual carbon dioxide emissions by 2030 compared with business as usual.[20]

Figure 9. Number of power plant equivalents avoided by energy efficiency since 1990, and potential through 2030. Estimates are based on power plants with an output of 500 MW.[21]



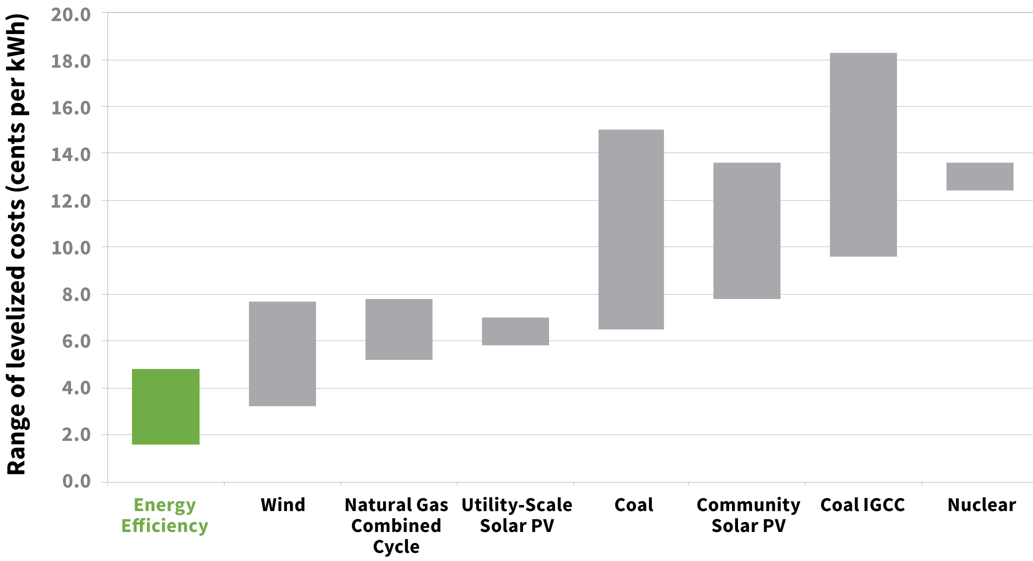
Delivers household savings of $840 per year

Over time, energy efficiency policies and programs have saved consumers billions by helping to lower their electricity bills and by keeping prices down.[22] Nationally, ACEEE estimates that customers are saving $90 billion annually on electricity bills from these policies and programs, for a total of nearly $790 billion in cumulative savings since 1990.[23] For residential customers, we estimate this translates into average annual savings of $840 per household in 2015 on electricity bills alone.[24] Not only do families and businesses that install energy efficiency measures save on electricity bills, but also on gas, fuel oil, and water.

Brings a return on investment of 200% or more

Efficiency reduces costs for everyone, not just for those who participate in energy efficiency programs, primarily by allowing utilities to defer or avoid the need to build new power plants.[25] Energy efficiency is much cheaper for utilities to implement than building new generating capacity (see figure 10). As shown, utility energy efficiency programs cost about 2 to 5 cents per kilowatt-hour, which is one-half to one-quarter the cost of other options.[26] And even as savings from programs have increased in recent years, the cost of saved energy holds steady, as ACEEE recently documented for 14 leading efficiency program administrators.[27] Every dollar invested in utility energy efficiency programs produces, on average, more than $2 to $4 in benefits for all customers.[28]

Figure 10. Levelized cost of electricity resources



Reduces energy burdens for households most in need

Access to energy efficiency is especially important for low-income households because it lowers energy bills over the long term and helps to alleviate their "energy burden," which is the percentage of household income spent on utility energy bills. A recent report by ACEEE finds that low-income households in 48 cities across the United States pay three times as much on their household energy bills as a percentage of their income than non-low-income households.[29] The report also finds that, on average, African-American households, Latino households, and renters, spend disproportionate amounts of their income on energy. More energy efficiency measures would help close the gap by at least one-third.

Also, many minority and low-income neighborhoods have been disproportionately burdened with the health harms that are by-products of both fossil fuel-fired electric generation and vehicle traffic.[30] Energy efficiency can be a tool to decrease emissions in these communities.

Improves health, safety, and comfort

Energy efficiency provides direct health benefits. Minimizing the amount of energy we waste reduces our need to burn coal and other fossil fuels to generate electricity. The resultant reductions in pollution mean big gains for health, as pollutants from fossil fuel combustion—including sulfur dioxide and nitrogen oxides—contribute to four of the leading causes of death in the United States: cancer, chronic lower respiratory diseases, heart disease, and stroke.[31]

Energy efficiency programs can also directly improve health, comfort, and safety for households and businesses. A typical program may include replacing outdated appliances, improving heating and cooling, upgrading lighting and insulation, and sealing out cold drafts. For many households, these non-energy benefits are the primary motivations for implementing efficiency upgrades. These programs can be targeted to ensure that benefits accrue to those homes and populations that most need them. This can be a lifesaver for low-income families and those living on fixed incomes, including seniors, veterans, and the disabled. In some cases, programs can be combined with needed building upgrades that also improve indoor air quality.

A Home Intervention Is a Health Intervention: The Ruiz Family

Chilly drafts, an ill-fitted window, leaky pipes, damaged walls, a moldy basement, pest infestations, and high electric bills. These were the nightmarish conditions in which Melissa Ruiz found herself. Melissa was a single mom who had purchased her home in North Philadelphia three years earlier. Melissa's daughter was now experiencing severe asthma symptoms daily. Eventually, after another trip to the Emergency Department at St. Christopher's Hospital for Children, the family was referred to the Healthy Homes Healthy Kids (HHHK) program of the Philadelphia Department of Public Health.

HHHK collaborated with the nonprofit Green and Healthy Homes Initiative and city agencies to repair Melissa's house. After a comprehensive environmental assessment, they sealed air leaks, insulated the basement, and repaired the windows to make the whole house more efficient and weatherproof. They fixed plumbing leaks and faulty electrical wiring. They removed the pest infestation, broken rain gutters, and the mold hazard. Since the intervention, Melissa's utility bills have decreased and her daughter's symptoms have improved. They have not been back to the emergency room. Melissa said the repairs made their home "healthier and safer for my daughter and my whole family." Since 2012 HHHK has fixed 177 homes of children with severe asthma in Philadelphia.

Increases community and grid resilience

Communities face a wide range of threats, like aging infrastructure and extreme weather such as droughts. Energy efficiency has an important role to play by helping keep electricity flowing during severe weather events and improving grid reliability.[32] For example, during Hurricane Sandy, while 8.5 million utility customers lost power, a small number of residential buildings, hospitals, universities, and water treatment plants kept power, heat, and critical operations running. This was made possible by combined heat and power (CHP) systems, a technology that makes efficient use of electricity and thermal energy at the same time.[33] CHP systems are not just backup generators; they provide both heat and electricity during regular operations and are highly efficient. Today, CHP is an important resource for the United States, with 84 gigawatts (GW) of existing capacity, or about 8% of US generating capacity.[34] CHP has the potential to contribute much more. The US Department of Energy estimates there is an additional 240 GW of technical potential for CHP installations at more than 291,000 sites in this country.[35]

In addition to CHP systems, district energy systems, microgrids, and high-efficiency buildings that allow residents to shelter in place when the power is out in their community all have a role to play as community resilience strategies.[36] These technologies and systems also enable energy reductions and cost savings for residents by improving efficiency. Energy efficiency combined with innovative water conservation measures can yield a double dividend of energy and water savings, which is of particular importance for communities impacted by drought. As the need to adapt to extreme weather events increases due to the changing climate, energy efficiency will play an important role in helping our communities to be stronger, safer, and more resilient.

Creates jobs and expands economic development

Energy efficiency provides opportunities for economic growth and job creation throughout the economy. Implementing energy efficiency has developed into a major economic force. One analysis finds that efficiency in the buildings sector is the largest segment of the clean energy economy, with $64 billion in annual revenue and 50% growth over the past five years.[37] The same analysis finds that efficiency in the industrial sector, which includes CHP and energy management systems, generated $7.7 billion in revenue in 2015, more than a twofold increase over the past five years; these metrics demonstrate the size of energy efficiency beyond the electricity sector alone. Facing the outsourcing of manufacturing jobs and other effects of globalization, policymakers are looking for lasting solutions that will reenergize the US workforce and create high-quality, permanent jobs. Energy efficiency creates employment opportunities that draw upon the broad range of Americans' skills.[38]

More important, cost-effective investments in energy efficiency drive economic growth and development by making businesses more competitive and easing household budgets. When businesses improve energy efficiency, they lower their cost of doing business, allowing them to increase market share, expand their operations, and add workers to their payrolls. For families, increasing efficiency makes it easier to make ends meet and frees up income to be spent in their communities, helping create local jobs and supporting stable economic development. At the macro level, energy efficiency enhances our economic productivity, the key to long-term competitiveness and growth. Previous research by ACEEE finds that in 2030, energy efficiency could add more than $17 billion to our GDP and create or save 611,000 jobs economy-wide through the adoption of state energy efficiency policies alone.[39]

History

Here is a brief history of major policy milestones that have made energy efficiency gains possible in the electricity sector.

1970s Demand for electricity was rapidly rising, with prices spiking after the 1973 oil crisis. Energy efficiency was recognized as an important strategy to keep electricity growth in check and to avoid or defer costly new infrastructure, thereby saving money for all ratepayers. In 1974 California established the first appliance efficiency standards through the Warren–Alquist Act, which was signed into law by Governor Ronald Reagan. This paved the way for several other states to enact their own standards and for future national standards. The 1978 National Energy Conservation Policy Act created the Residential Conservation Service requirement that utilities provide energy conservation audits for their customers, triggering the first widespread utility involvement in energy efficiency programs.

1980s The 1980 Pacific Northwest Electric Power Planning and Conservation Act, signed by President Jimmy Carter, enshrined in federal law the concept that energy efficiency is a resource. Starting in 1987, Congress enacted a series of laws on a broadly bipartisan basis that set specific appliance and equipment efficiency standards and required the US Department of Energy to update them periodically. Utilities began offering energy efficiency programs for their customers, and regulators in many states required utilities to consider energy efficiency as an alternative to electricity supply options.

1990s Policy action in this decade spurred major growth in building energy codes, which set minimum requirements for energy-efficient design and construction. In the utility sector, however, there was an overall decline in efficiency investments as many states restructured electricity generation markets and abandoned or scaled back investments in energy efficiency through utility programs. Utility energy efficiency program spending dropped by 50% from 1994 to 1998.

2000s to today Following the California/West Coast electricity crisis of 2000, there has been a rebirth of the concept of energy efficiency as a utility system resource. Utility energy efficiency programs and state policies that encourage such programs have grown substantially. Annual utility energy efficiency program investments have expanded from $1.6 billion in 2006 to $7 billion in 2014. (However these investments and their resulting savings vary by region; in 2014 only 16 states achieved energy savings of at least 1% of sales, relative to the prior year.) Local governments have made significant strides, especially since the 2009 American Recovery and Reinvestment Act (ARRA), which was an economic stimulus signed by President Barack Obama to address the Great Recession. ARRA included many provisions for energy efficiency improvements.

Policy is the driving force behind our energy efficiency success

Our nation's advances in energy efficiency didn't happen without help. Efficiency faces persistent market and other barriers that we have had to work to overcome. Energy efficiency policies have a proven track record of success, and aiming for higher savings could lead to a cleaner and less wasteful electricity system even as utilities adapt to the changing energy landscape.[40]

Barriers to energy efficiency

- **Imperfect information:** Consumers have limited awareness of energy performance of equipment and buildings and limited access to energy usage data.
- **Split incentives:** Rental properties are a common example. Because tenants pay the energy bills, landlords have little incentive to make efficiency investments to reduce energy bills.
- **Regulatory and legal barriers:** In many electric utility business models, greater profits are tied to selling more energy and making more capital investments. These objectives are at odds with energy efficiency, whose goal is to reduce energy waste.
- **Externalities:** The environmental, health, and security costs to society of energy production and transmission are not added to energy prices. Although energy efficiency helps reduce these costs, the savings are rarely recognized.

Policies that work

Proactive policies and strategies that address the barriers to energy efficiency can create the conditions and incentives for utilities, manufacturers, retailers, energy service companies (ESCOs), and other businesses to develop and provide more efficient technologies, equipment, and appliances. Some of these successful policies for electricity savings include:

- **Appliance and equipment efficiency standards**, which prohibit the production and import or sale of appliances and other energy-consuming products that fall below minimum performance requirements while still leaving consumers a wide array of more efficient products to choose among.
- **Building energy codes**, which set minimum requirements for energy-efficient design and construction for new and renovated buildings.
- **Energy efficiency targets**, energy savings goals set for utilities to meet through programs that help customers save energy.
- **Utility regulatory reforms** that change the utility business model so that utilities are incentivized to provide energy efficiency services to customers instead of selling more electricity and investing in unnecessary electricity generation resources. These changes will help utilities prioritize efficiency in their resource plans.

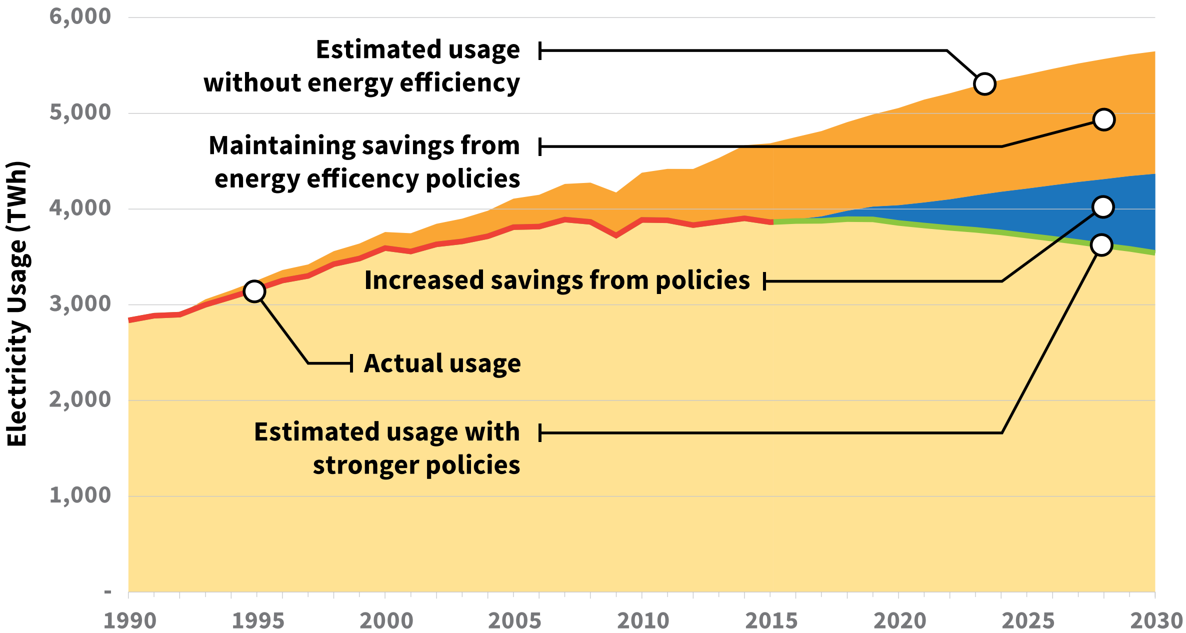
The federal government, states, localities, and utilities have made significant strides to improve efficiency with these strategies as well as several others, such as EPA's ENERGY STAR® program, energy service performance contracting, and city-led building energy benchmarking initiatives.[41] Today, appliances and buildings use less electricity per person than in the past.[42] But we can save even more energy by defending past policy gains and charting new strategies.

Savings from policies can keep growing

Policies that promote energy efficiency have led to large savings, and they can still do much more. ACEEE estimates that if we extend a well-designed and proven set of federal, state, and local policies, the United States could save 1,000 terawatt-hours in 2030 (see the middle wedge of figure 11). This policy scenario assumes that all states adopt strong building energy codes, the federal government and/or states adopt new appliance efficiency standards, and all utilities ramp up programs to save at least 1.5% of total electricity sales per year.[43]

These policies and programs work by tapping into a large well of savings opportunities made possible by the next generation of energy efficiency technologies. In a recent study, ACEEE analyzed 18 measures—including reducing plug loads, conservation voltage reduction, and smart manufacturing—that could collectively save 22% of total projected electricity use in 2030.[44] Another recent analysis finds that electricity savings of 30% in 10 years are possible with the right set of conditions.[45] These savings could effectively bend the curve of energy consumption so we use increasingly less energy while growing our economy.

Figure 11. Estimated savings from both maintaining and increasing energy efficiency policies through 2030



LED lighting: How policy has enabled large energy savings

Lighting is an excellent example of how advanced technologies, policies, and programs can break down market barriers to improved energy efficiency. The 2007 Energy Independence and Security Act (EISA) improved energy efficiency for lightbulbs by establishing a process for setting progressively higher efficiency standards through 2020. As a result, today consumers have more and better lighting choices than ever before. Light emitting diode (LED) bulbs barely existed in 2007; today there are more than 1,650 models on the market, and sales are growing fast. LED bulbs are similar in appearance to old-fashioned incandescent lightbulbs and create the same kind of light, but LEDs last longer (10 to 25 years) and use less than one-quarter the energy of incandescent bulbs. As sales of LED bulbs have risen, their prices have dropped. Consumers can now find energy-efficient LEDs for $3–5 each, and prices are expected to drop further.

By setting a schedule for minimum efficiency levels that all manufacturers must meet, standards have reduced uncertainty in the marketplace, encouraged competition among manufacturers, and spurred innovation. Programs offered by electric utilities in many states have complemented these standards by bringing down the initial higher up-front cost. And with the rapid evolution of the lighting market, utilities have successfully shifted their offerings to adapt. The success of LED lighting as a way to help lower customer energy bills while improving customer satisfaction can be directly attributed to both federal and state energy efficiency policies as well as government-supported research in advanced technologies.

Policy should prioritize energy efficiency as the utility industry and clean technologies evolve

Policymakers and utilities can work toward an efficient and clean energy future by prioritizing efficiency as a resource in utility business models.[46] The electric power sector is currently undergoing rapid transformation, in part due to the increased use of technologies that can be located closer to the customer, such as solar power, energy storage, and electric vehicles. Because of its reliability and low cost, efficiency should be a partner to these clean technologies, helping them scale up as the market continues to develop. To take one example, buildings can combine energy efficiency with clean technologies to lower emissions and achieve "zero net energy."

Energy efficiency and renewable energy working together can lower a building's carbon footprint to zero

Energy efficiency and improved building performance can dramatically lower a building's energy use and utility costs while optimizing comfort and improving indoor air quality. This makes it possible for renewable energy—such as solar panels—to produce enough energy to supply the remaining needs. The result is a zero net energy (ZNE) building or home, one with no carbon footprint. The New Buildings Institute has identified nearly 200 ZNE commercial buildings in the United States in the public and private sectors, including schools, offices, and multifamily structures, and has found that on average they use only a quarter of the energy of average buildings.[47] There are also more than 6,600 ZNE homes across the country.[48] The improved efficiency and performance in these homes and buildings make it possible to downsize their mechanical systems and renewable energy requirements.

How to create an energy-efficient future

An energy-efficient future won't happen on its own. There are still barriers to overcome, research to be conducted, technologies to develop, investments to make, and policymakers to convince. Implementation has been uneven at the state and local levels, as ACEEE has documented in its annual policy *Scorecards*.[49] Critical support is needed from government, industry, and the nonprofit community so that scientists, analysts, and advocates can continue the full-court press to save energy everywhere it's wasted.

Energy efficiency alone cannot meet all of this country's or the world's climate goals. However, by decreasing the amount of energy we waste and recognizing the role of energy efficiency in powering our economy and livelihoods, we can ensure a more prosperous future for all Americans while addressing our environmental challenges. Just as energy efficiency policies have led to significant gains over the past 40 years, a new era of visionary policy can create opportunity and drive progress for future generations.

Figure Sources

1. ACEEE analysis (aceee.org/blog/2015/12/what-energy-intensity-and-how-does-it) based on US Energy Information Administration (EIA) data from *January 2015 Monthly Energy Review* www.eia.gov/totalenergy/data/monthly/archive/00351501.pdf and on H. Huntington, "Structural Change and U.S. Energy Use: Recent Patterns," *Energy Journal* 31 (3), June 2010. www.researchgate.net/profile/Hillard_Huntington/publication/227363591_Structural_Change_and_U.S._Energy_Use_Recent_Patterns/links/0c96052f2d59032b3d000000.pdfH.

2. Data for electricity usage and for gross domestic product (GDP) are both from *EIA May 2016 Monthly Energy Review*, Table 7.6 and Table C1, respectively. www.eia.gov/totalenergy/data/monthly/.

3. US EPA, "Greenhouse Gas Inventory Data Explorer," data for all sectors and all GHGs in 2014.

4. International Energy Agency (IEA).

5. EIA for all except energy efficiency, which is based on ACEEE estimates. EIA data source is *May 2016 Monthly Energy Review*, Table 7.2a Electricity Net Generation: Total (All Sectors).

6. Same as figure 5.

7. EIA 2016 early release reference case for all except energy efficiency, which is based on ACEEE estimates. EIA data source is *Annual Energy Outlook, 2016 Early Release*, May 2016, "Electricity Supply, Disposition, Prices, and Emissions" Reference Case, Net Electricity Generation data. www.eia.gov/forecasts/aeo/er/index.cfm.

8. Same as figure 7.

9. Based on ACEEE's analysis presented in this paper.

10. Energy efficiency costs from M. Molina, *The Best Value for America's Energy Dollar: A National Review of the Cost of Utility Energy Efficiency Programs* (Washington, DC: ACEEE, 2014). aceee.org/research-report/u1402. All other data from Lazard, *Levelized Cost of Energy Analysis Version 9.0* (New York: Lazard, Ltd., 2015).

11. Based on ACEEE's analysis presented in this paper.

End Notes

1. A quadrillion is 10 to the 15th power. aceee.org/blog/2015/12/what-energy-intensity-and-how-does-it.

2. aceee.org/blog/2014/02/us-electricity-use-declining-and-ener. Stanford University's Energy Modeling Forum examined energy productivity gains over the 1997–2006 period in a 2009 report and estimated that 39% of the improvement during this period was due to structural shifts in the economy and 61% was due to intensity improvements within each of the 65 sectors they examined. H. Huntington, "Structural Change and U.S. Energy Use: Recent Patterns," *Energy Journal* 31 (3), June 2010. www.researchgate.net/profile/Hillard_Huntington/publication/227363591_Structural_Change_and_U.S._Energy_Use_Recent_Patterns/links/0c96052f2d59032b3d000000.pdfH.

3. aceee.org/blog/2016/03/us-electricity-use-no-longer-growing.

4. Environmental Protection Agency (EPA), "Sources of Greenhouse Gas Emissions." www3.epa.gov/climatechange/ghgemissions/sources.html.Environmental Protection Agency. "Sources of Greenhouse Gas Emissions" https://www3.epa.gov/climatechange/ghgemissions/sources.html

5. According to the International Energy Agency (IEA), the 450 Scenario sets out an energy pathway consistent with the goal of keeping the global increase in temperature to 2°C by limiting concentration of greenhouse gases in the atmosphere to around 450 parts per million of CO_2. IEA, *World Energy Outlook 2015* (Paris: IEA 2015). www.iea.org/publications/scenariosandprojections/

6. www.epa.gov/cleanpowerplan.

7. C. Kubes, S. Hayes, and M. Kelly, *State and Utility Pollution Reduction Calculator Version 2 (SUPR 2)* (Washington, DC: ACEEE, 2016). aceee.org/research-report/e1601.

8. There is also spillover from electricity energy efficiency into the other sectors. For example, when new measures are installed in commercial and residential buildings to save electricity, they often also save other energy sources for space heating such as natural gas and fuel oil. This is an example of the multiple benefits of energy efficiency. Non-electric energy savings contribute to additional greenhouse gas emissions reductions.

9. US Department of Energy (DOE), "Transportation Energy Futures Project." www.nrel.gov/analysis/transportation_futures.

10. Due largely to the superior efficiency of electric motors relative to internal combustion engines, a battery-electric vehicle today is substantially more energy efficient than a conventional vehicle of comparable size—even when the losses associated with electric power generation are factored in. While the efficiency of gasoline-powered vehicles is on the rise, even the more advanced ones produce much more CO_2 than an EV charged on a clean grid: on a full-fuel-cycle basis, a 2016 Ford Focus Electric in the relatively clean Northeast Power Coordinating Council/NYC Westchester region is responsible for 55% less CO_2 emissions than a 2016 Toyota Prius. This estimate is based on ACEEE's Greener Cars 2016 EV calculator, greenercars.org/news/electric-vehicle-calculator.

11. For example, most transmission planners include energy efficiency in their forecasts, and several also include it in generating capacity markets. See ISO New England, *Final 2015 Energy-Efficiency Forecast for 2019–2024* (Holyoke, MA: ISO New England, 2015). www.iso-ne.com/static-assets/documents/2015/04/iso_ne_final_2015_ee_forecast_2019_2024.pdf.

12. www.nwcouncil.org/energy/powerplan/7/plan/ and www.nwcouncil.org/news/blog/7th-pp-approved/.

13. ACEEE estimated the size of energy efficiency in the US electric power sector through a bottom-up approach by examining documented electricity savings from 1990 through 2015 from impacts of policies and programs. We chose 1990 as the starting point because consistent sets of available data started around that time. Some states and regions (e.g., California and the Northwest) have data back to the 1970s. All assumptions in this analysis have limitations and uncertainty. We first collected state-level estimates of savings at the customer meter from three sets of policies and programs:

1) Appliance and equipment efficiency standards from the Appliance Standards Awareness Project's (ASAP) updated analysis for A. Lowenberger et al., *The Efficiency Boom: Cashing In on the Savings from Appliance Standards* (Washington, DC: ACEEE, 2012). aceee.org/research-report/a123.

2) Utility-sector energy efficiency programs from ACEEE's *State Scorecard* data for incremental annual net electricity savings by state. aceee.org/state-policy/scorecard.

3) Building energy codes derived from estimates by the Pacific Northwest National Laboratory (PNNL): O. Livingston et al., *Building Energy Codes Program: National Benefits Assessment, 1992–2040* (Richland, WA: PNNL, 2014). www.energycodes.gov/sites/default/files/documents/BenefitsReport_Final_March20142.pdf.

We then summed state-level savings estimates to a national total. Because end-use energy efficiency also avoids electricity lost through the transmission and distribution process, we convert savings at the customer meter to savings at the generation level by adding avoided line losses of 6.2%, which is the national average per the EPA. www.epa.gov/chp/chp-benefits - tabs.

14. This estimate assumes a 500 MW coal-fired power plant (per the "Rosenfeld" analysis, iopscience.iop.org/article/10.1088/1748-9326/5/1/014017) and a capacity factor of 64%, the average capacity factor for coal plants in the United States 2008–2013. (www.eia.gov/electricity/monthly/current_year/february2014.pdf). http://www.eia.gov/electricity/monthly/current_year/february2014.pdf

15. There were nearly 300 coal power units in Germany in 2012, which accounted for about 51,000 MW of capacity (www.iea.org/publications/freepublications/publication/CCS_Retrofit.pdf). Our estimate is three times as much as coal capacity in Germany because we assume a 500 MW power plant, for a total of 156,586 MW avoided. In the United States there were nearly 1400 coal power units in 2012, which accounted for about 340,000 MW of capacity.

16. We estimated potential future impacts of energy efficiency policies, relying on previously published projections of savings for appliance and equipment standards, utility-sector energy efficiency programs, and building energy codes. For new appliance and equipment efficiency standards, we relied on the Appliance Standards Awareness Project. For utility efficiency programs, savings ramp up to 1.5% per year, as indicated in *The State and Utility Pollution Reduction (SUPR) Calculator*. Savings from new building energy codes are also based on the SUPR calculator. As with any forecast, all assumptions in this analysis have limitations and uncertainty. C. Kubes, S. Hayes, and M. Kelly, *The State and Utility Pollution Reduction Calculator (SUPR) Version 2* (Washington DC: ACEEE, 2016). aceee.org/research-report/e1601.

17. See E. Rogers et al., *How Information and Communications Technologies Will Change the Evaluation, Measurement, and Verification of Energy Efficiency Programs* (Washington, DC: ACEEE, 2015). aceee.org/research-report/ie1503.

18. For example, see the DOE's Uniform Methods Project (energy.gov/eere/about-us/ump-home) and the National Efficiency Screening Project (www.nationalefficiencyscreening.org/).

19. For a discussion of the full range of benefits of energy efficiency, see J. Lazar and K. Colburn, *Recognizing the Full Value of Energy Efficiency* (Montpelier, VT: Regulatory Assistance Project [RAP], 2013). www.raponline.org/event/recognizing-the-full-value-of-efficiency-theres-more-layers-in-the-layer-cake-than-many-account.

20. Using eGRID subregion annual CO_2 total output emission rate (lb/MWh), and applied to 1990–2030 total savings.

21. See note 14.

22. Energy efficiency keeps prices down relative to what they would be without energy efficiency, in part because efficiency is cheaper than the alternatives. Also, in wholesale markets, reduced demand from energy efficiency can reduce wholesale market prices. For a full discussion of this price suppression effect and other utility system benefits that accrue to all customers in a utility system, see B. Baatz, *Everyone Benefits: Practices and Recommendations for Utility System Benefits of Energy Efficiency* (Washington, DC: ACEEE, 2015). aceee.org/everyone-benefits-practices-and-recommendations.

23. This savings estimate is gross retail savings, using statewide average real electricity prices (in 2014 dollars) from the Energy Information Administration (EIA). Price forecasts through 2030 are based on EIA's *2015 Annual Energy Outlook* by applying national average year-over-year changes to statewide electricity prices.

24. We calculated this estimate for 2015 by first assigning a portion (55%) of total electricity savings to the residential sector. The 55% estimate is based on a median of utility efficiency savings (45% per Molina 2014) and appliance efficiency standards (64% per the Appliance Standards Awareness Project). We then divide savings by the total number of US households in 2015, and multiply per-household savings by the average national residential electricity price of 12.67 cents in 2015 (per EIA's April 2016 Monthly Energy Review; annual average for 2015). M. Molina, 2014, *The Best Value for America's Energy Dollar: A National Review of the Cost of Utility Energy Efficiency Programs* (Washington, DC: ACEEE, 2014). aceee.org/research-report/u1402. Energy Information Administration (EIA), *April 2016 Monthly Energy Review* (Washington, DC: EIA). www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf.

25. Other benefits to the electricity system—and all customers in that system—include reduced investments in transmission and distribution (T&D) infrastructure and reduced exposure to fuel price volatility.

26. M. Billingsley et al., *The Program Administrator Cost of Saved Energy for Utility Customer-Funded Energy Efficiency Programs in the United States* (Berkeley: Lawrence Berkeley National Laboratory, 2014). emp.lbl.gov/sites/all/files/lbnl-6595e.pdf. M. Molina, 2014, *The Best Value for America's Energy Dollar: A National Review of the Cost of Utility Energy Efficiency Programs* (Washington, DC: ACEEE, 2014). aceee.org/research-report/u1402.

27. B. Baatz, A. Gilleo, and T. Barigye, *Big Savers: Experiences and Recent History of Program Administrators Achieving High Levels of Electric Savings* (Washington, DC: ACEEE, 2016). aceee.org/research-report/u1601.

28. One study found that utility efficiency programs returned on average $2.40 in benefits for every $1 invested, based on data from nine states. M. Molina, *The Best Value for America's Energy Dollar: A National Review of the Cost of Utility Energy Efficiency Programs* (Washington, DC: ACEEE, 2014). aceee.org/research-report/u1402. Analysis on appliance standards estimates total benefits of $4 for every $1 of investment. A. Lowenberger et al., *The Efficiency Boom: Cashing In on the Savings from Appliance Standards* (Washington, DC: ACEEE, 2012). aceee.org/research-report/a123.

29. A. Drehobl and L. Ross, *Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low Income and Underserved Communities* (Washington, DC: ACEEE, 2016). aceee.org/research-report/u1602.

30. L. Clark, D. Millet, and J. Marshall, "National Patterns in Environmental Injustice and Inequality: Outdoor NO_2 Air Pollution in the United States," PLoS ONE 9(4): e94431, 2014. journals.plos.org/plosone/article?id=10.1371/journal.pone.0094431.

31. aceee.org/fact-sheet/ee-and-health.

32. D. Ribeiro et al., *Enhancing Community Resilience through Energy Efficiency* (Washington DC: ACEEE, 2015). aceee.org/research-report/u1508.

33. Combined heat and power (CHP) is a fuel-efficient, distributed generation technology that avoids transmission and distribution losses and can lead to significant system reliability and air quality benefits. According to the EPA, a typical 5 MW CHP system produces about half the annual CO_2 emissions of conventional power generation (assuming US average heat rate and emissions factors for avoided grid generation, and using EPA's CHP emissions calculator). See aceee.org/blog/2012/12/how-chp-stepped-when-power-went-out-d.

34. See www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf.

35. See energy.gov/sites/prod/files/2016/03/f30/CHP Technical Potential Study 3-18-2016 Final.pdf.

36. District energy systems produce steam and hot or chilled water at a central plant, which is then piped underground to individual buildings for space heating, water heating, and air conditioning. Microgrids are local power grids that connect a selection of buildings and facilities to distributed energy supplies, such as CHP, district energy systems, solar photovoltaic systems, and energy storage devices.

37. Advanced Energy Economy, *Advanced Energy Now: 2016 Market Report* (Washington, DC: Advanced Energy Economy, 2016). info.aee.net/aen-2016-market-report.

38. C. Bell, *Energy Efficiency Job Creation: Real World Experiences* (Washington, DC: ACEEE, 2012). aceee.org/white-paper/energy-efficiency-job-creation.

39. S. Hayes et al., *Change Is in the Air: How States Can Harness Energy Efficiency to Strengthen the Economy and Reduce Pollution* (Washington, DC: ACEEE, 2014). aceee.org/research-report/e1401.

40. See S. Vaidyanathan et al., *Overcoming Market Barriers and Using Market Forces to Advance Energy Efficiency* (Washington, DC: ACEEE, 2013) aceee.org/research-report/e136; and M. Kushler and P. Witte, *Can We Just "Rely on the Market" to Provide Energy Efficiency? An Examination of the Role of Private Market Actors in an Era of Electric Utility Restructuring* (Washington, DC: ACEEE, 2001). aceee.org/research-report/u011.

41. For example, see this ACEEE analysis, aceee.org/blog/2015/07/which-energy-efficiency-policies, and DOE's "Estimates of National Electricity and Carbon Savings Potential in 2030," www.energy.gov/eere/slsc/energy-efficiency-savings-opportunities-and-benefits - estimates. As noted in the DOE resource, those various policy options may include overlapping savings, so their estimates are not additive.

42. S. Nadel, R. N. Elliott, and T. Langer, *Energy Efficiency in the United States: 35 Years and Counting*. (Washington, DC: ACEEE, 2015). aceee.org/research-report/e1502.

43. This is the same set of policy assumptions as previously described. We estimate that the majority of these savings are beyond those forecast by the EIA for 2030. EIA, "2016 Annual Energy Outlook, Early Release." www.eia.gov/forecasts/aeo/er/index.cfm. However we assumed that one-third of projected savings from utility energy efficiency programs are already accounted for in EIA's forecast. In this chart, the line in between the top wedge and the middle wedge represents EIA's forecast for electricity usage.

44. D. York et al., *New Horizons for Energy Efficiency: Major Opportunities to Reach Higher Electricity Savings by 2030* (Washington, DC: ACEEE, 2015). aceee.org/research-report/u1507.

45. C. Neme and J. Grevatt, *The Next Quantum Leap in Efficiency: 30 Percent Electric Savings in Ten Years* (Montpelier, VT: The Regulatory Assistance Project, 2016). raponline.org/document/download/id/7944.

46. S. Nadel and G. Herndon, *The Future of the Utility Industry and the Role of Energy Efficiency* (Washington, DC: ACEEE, 2015). aceee.org/research-report/u1404.

47. New Buildings Institute (NBI), *2014 Getting to Zero Status Update*. newbuildings.org/wp-content/uploads/2014/01/2014_Getting_to_Zero_Update.pdf.

48. Net-Zero Energy Coalition (NZEZ), *To Zero and Beyond: Zero Energy Residential Buildings Study*, 2015. netzeroenergycoalition.com/wp-content/uploads/2015/04/20150105_nzec_zero_energy_homes_report_booklet_fnl_02.pdf.

49. See ACEEE's *State and City Energy Efficiency Scorecards*: aceee.org/state-policy/scorecard and aceee.org/local-policy/city-scorecard.

Photo Credits

Photo on Page 1: Curt Beyer, vice president of manufacturing at Landmark Homes, © Flickr user Green Energy Futures, CC 2.0 Attribution. Photo on Page 13: NRC, Feb. 2013 - U.S. House Subcommittee Hearing, © Flickr user NRC, CC 2.0 Attribution. All other photo images © istockphoto.com.

Authored by Maggie Molina, Patrick Kiker, and Seth Nowak. August 2016.

The authors thank the Energy Foundation for supporting this work. We also thank our ACEEE colleagues who helped with the analysis, writing, editing, and production of this report. Finally, we are grateful to the many other energy efficiency experts who reviewed a draft of this report and provided comments.

ACEEE
American Council for an Energy-Efficient Economy