Natural Gas Energy Efficiency: Progress and Opportunities

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About the Author

Steven Nadel has been ACEEE's executive director since 2001. He has worked in the energy efficiency field for more than 30 years and has over 200 publications. His current research interests include state and federal energy policy, utility sector energy efficiency programs and policies, and strategies for transforming markets for efficient products and practices. He joined ACEEE in 1989 and served as deputy director of the organization and director of the Utilities and Buildings programs. Prior to ACEEE, Steve planned and evaluated energy efficiency programs for New England Electric, a major electric utility; directed energy programs for the Massachusetts Audubon Society, the state's largest environmental organization; and ran energy programs for a community organization working on housing rehabilitation in the poorest neighborhoods of New Haven, Connecticut. Steve earned a master of science in energy management from the New York Institute of Technology and a master of arts in environmental studies and a bachelor of arts in government from Wesleyan University.

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Executive Summary

The majority of papers and studies on utility-funded energy efficiency programs focus on electricity; natural gas receives much less attention. To help rectify this imbalance, this report seeks to: (1) provide a brief summary of natural gas efficiency efforts and accomplishments, and (2) look ahead at natural gas efficiency-related opportunities and issues.

To evaluate long-term efficiency trends, we looked at national natural gas consumption per an appropriate unit for residential, commercial, and industrial natural gas consumption. Figure ES1 shows these trends. In general, normalized consumption increased until around the time of the 1973 energy crisis, declined steeply until approximately 1985 when energy prices declined, and was level for about a decade thereafter. Consumption began declining again around 1995, particularly in the residential sector. The decline has been slightly less in the industrial sector, where inexpensive natural gas displaced other fuels, even as total energy consumption per dollar of shipments declined.

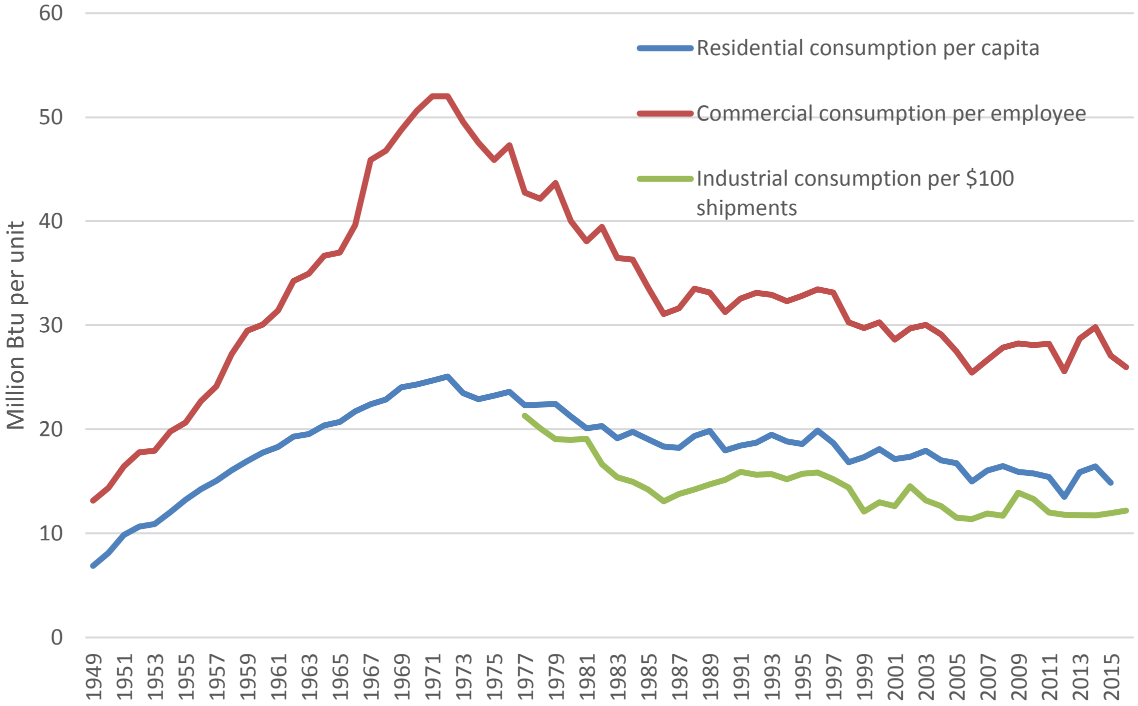

Figure ES1. Normalized sectoral natural gas consumption, 1949–2016. Data are not adjusted for weather. *Sources:* EIA 2017d for consumption and population, BLS 2017 for employees, FRED 2017 for industrial shipments.

CONTRIBUTORS TO NATURAL GAS EFFICIENCY PROGRESS

Many factors have likely contributed to this efficiency progress, although it is difficult to show direct cause and effect. Major likely contributors include the following.

New technologies. New, more efficient technologies continue to be developed. Examples include condensing gas furnaces and boilers (which condense water vapor in exhaust gases, recovering most of the heat used to evaporate this water); more efficient clothes washers, dishwashers, showerheads, and faucets (which reduce hot water use); more efficient water heaters (which improve combustion efficiency and reduce storage losses); and more efficient industrial processes. These developments in turn are supported by public and private research and development (R&D), as well as many of the policies discussed below.

Price effects. Changes in natural gas prices affect efficiency investments. In particular, efficiency increased substantially during the 1973–1984 period when gas prices rose. Since then, the effect of prices has been more muted; efficiency has been essentially level, even as prices declined in the late 1980s, and it improved only modestly when natural gas prices climbed steeply over the 1996–2008 period (see figure ES-1).

Building codes. Since 1980, the average energy use of new homes and commercial buildings that just meet national model building codes has declined by nearly 40% and 50%, respectively. Pacific Northwest National Laboratory (PNNL) estimates that building codes reduced total US energy use by about 0.5 quadrillion Btu (quads) in 2012 and will save 2.2 quads in 2040; unfortunately, PNNL does not provide a breakdown on natural gas savings versus savings in other fuels.[1] Given that the United States uses about 100 quads of energy each year, these savings translate into total reductions in US energy use in 2012 and 2040 of about 0.5% and 2.2%, respectively.

Appliance and equipment efficiency standards. State and federal minimum efficiency standards affect the energy use of various gas-related products such as residential and commercial furnaces, boilers, and water heaters, and hot-water-consuming products such as clothes washers, dishwashers, showerheads, and faucets. In 2015, these savings equaled about 4% of US natural gas, propane, and fuel oil consumption (the data combine the three fuels, although most of the savings were in natural gas).

Utility-funded energy efficiency programs. Natural gas utilities often operate energy efficiency programs for their end-use customers and sometimes fund programs operated by third-party organizations. In 2015, gas utilities spent about $1.4 billion on energy efficiency programs, with savings from measures installed in 2015 amounting to approximately 0.43% of residential and commercial natural gas sales. But some leading states and utilities are achieving incremental annual energy savings of more than 1% of residential and commercial sales each year and achieved total annual savings of more than 4% in 2015 (including measures installed in 2015, as well as measures installed in earlier years that were still saving energy in 2015). These programs cost the utilities an average of approximately 35 cents per therm saved (a therm is 100,000 Btu of energy content, and is the unit used to bill customers for natural gas). Most of the high-saving states have mandatory energy savings targets for their utilities; such targets are commonly called *energy efficiency resource standards*. These states also frequently take steps to provide a performance incentive for utilities that successfully pursue energy efficiency for their customers.

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[1] O. Livingston, P. Cole, D. Elliott, and R. Bartlett, *Building Energy Codes Program: National Benefits Assessment, 1992–2040* (Richland, WA: Pacific Northwest National Laboratory, 2013). www.greenbuildinglawblog.com/uploads/file/DOE%20Building%20Energy%20Code%20Savings%20Report%20Oct%202013%281%29.pdf.

THE FUTURE

Although natural gas efficiency savings have increased over time, in recent years, natural gas consumption has been slowly increasing. This increased consumption has primarily been in the electric power and industrial sectors, with residential and commercial consumption essentially remaining level. Further, transportation consumption is small but growing. The Energy Information Administration (EIA) projects that these trends will continue, with growth primarily in the industrial sector, and consumption for electric power generation leveling off through the 2020s, then increasing again in the 2030s.

These projections do not factor in all energy efficiency opportunities. Many studies have been conducted on additional efficiency opportunities, finding that incremental annual gas savings of about 1% of sales can be achieved over the next 10–20 years. These studies show that, despite the current low price of natural gas, there are still substantial cost-effective natural gas savings available. The reason for this is that many efficiency measures profiled in these recent studies cost less per cubic foot of gas than the current price of natural gas. Across the different studies, large gas saving opportunities remain for the industrial sector, residential and commercial building retrofits, advanced controls, commercial new construction, and residential water heating.

OTHER ISSUES AND OPPORTUNITIES

Various other issues related to energy efficiency opportunities and the natural gas industry's evolution are worth noting.

Combined heat and power. Combined heat and power (CHP) is generally the most energy-efficient method of generating power available today. Natural gas CHP systems can have efficiencies of 80% or more—much better than the approximately 45% average annual efficiency of gas combined-cycle power plants. CHP systems obtain these efficiencies by making use of waste heat. Today, 83 GW of CHP capacity is in operation, with about 47 GW of additional economic potential. One promising option for developing some of this additional potential is for electric or natural gas utilities to build and finance these plants, earning their normal rate of return on the investments. Presently, more than 3 GW of utility-owned CHP plants are in operation and more are on the drawing board.

Transportation fuels. Natural gas can be used as a transportation fuel, either as compressed natural gas (CNG) or liquefied natural gas (LNG). Natural gas engines are spark ignited, similar to gasoline engines, and they have similar efficiencies. Thus, burning natural gas in an engine is generally no more or less efficient than burning gasoline or diesel fuel. Natural gas can be used in some transportation applications to reduce costs or emissions. For example, using natural gas may make sense for fleets if vehicles travel enough miles and use enough fuel to provide a reasonable payback, and they generally operate near natural gas fueling stations.

Compared to gasoline and diesel vehicles, natural gas vehicles are generally cleaner in terms of emissions of major criteria pollutants. Tailpipe greenhouse gas emissions from natural gas vehicles are lower as well and can be reduced further using renewable natural gas, but this benefit is offset to varying degrees by methane leakage at various stages in the fuel cycle. Energy use and emissions of battery electric vehicles can be lower than natural gas vehicles. For long-haul trucks, the keys to the future for natural gas will be the price of natural gas relative to diesel fuel, and developing a national refueling infrastructure for LNG at truck stops. In sum, opportunities for natural gas vehicles appear to be modest, limited to some fleets and applications.

Coordination between natural gas and other utilities. Marketing energy efficiency to residential and small commercial customers is expensive. To maximize energy savings and economic benefits, it makes sense for gas, electric, and water utilities to work together, sharing costs for marketing and for measures that save electricity, gas, and water. Many successful examples of cooperation have been documented.

Fuel switching. Electrifying various end-uses over multiple decades to reduce emissions is an approach gaining increased attention. Natural gas has lower emissions than other fossil fuels, and it presently has a lower price. Thus, for the time being, most electrification efforts focus on displacing oil and propane, including for vehicles and space and water heating. But in the long-term, emissions from electricity can be lower than from natural gas if electricity is primarily generated from renewable and nuclear energy or other zero- or near-zero emissions sources.

A study on the energy use and economics of gas furnaces and electric heat pumps found that installing a new electric heat pump when replacing an existing central air conditioner often results in energy and economic savings in the south and west, but at present does not generally make sense in the north. However new technologies can change this comparison in the north, with cold climate electric heat pumps (optimized for operation at low temperatures) generally having lower energy use than condensing furnaces, but gas heat pumps (driven by gas instead of electricity) often outperforming cold climate heat pumps.

CONCLUSION

Energy efficiency has resulted in substantial natural gas savings. Considerable opportunities remain for additional cost-effective savings, with the achievable savings averaging about 1% of gas sales each year for the next decade or more. Recent studies have found that these savings are cost effective, even at today’s relatively low natural gas prices. Natural gas is a large portion of our energy mix, and we have many opportunities to use it more wisely to manage resources, keep energy bills in check, and keep emissions to modest levels. By doing so, we can improve the US economy and environment.

Introduction

At ACEEE, we have written extensively about energy efficiency efforts, including efforts to reduce the use of electricity, natural gas, and other fuels. However, because electric utility revenues are more than three times those of natural gas utility revenues[2] and (as we describe later) utility energy efficiency spending is much greater for electricity than for natural gas, our writings have focused more on electricity efficiency (with some exceptions, e.g., York et al. 2012; Young, Elliott, and Kushler 2012; and Elliott and Shipley 2005). Recently, however, we rounded-up extensive information about natural gas efficiency for a talk to the Gas Technology Institute Public Interest Advisory Committee. We present this research here as a report so that many more people can learn and benefit from the information we gathered. Our objectives are two-fold:

- Provide a brief summary of natural gas efficiency efforts and accomplishments
- Look ahead at efficiency-related opportunities and issues

We divide this report into seven sections. First, we provide a very brief overview of the major natural gas industry players. We then look at natural gas efficiency trends and factors that have contributed to them, including new technologies, changing prices, building codes, and appliance and equipment efficiency standards. Next, we delve into utility energy efficiency programs in more depth, including spending, savings, and key policy drivers. Following this, we look into the future, considering forecasts for natural gas consumption and recent studies on energy efficiency opportunities. We then discuss various other efficiency-related issues, including combined heat and power (CHP) systems; transportation fuels; coordination between electric, natural gas, and water utilities; and fuel switching. We finish with some brief conclusions.

The Natural Gas Industry

Among the natural gas industry's many players are the following:

- Natural gas producers (large oil and gas companies, as well as smaller independent production companies)
- Pipeline companies that transport gas from major hubs in production regions to major markets
- Local distribution companies (LDCs) that distribute gas to small and medium-sized customers (also known as gas utilities)
- Large end users that buy natural gas direct from producers, pipeline companies, or other wholesalers
- Retail utility customers including households, commercial businesses, and smaller industrial enterprises that purchase gas from LDCs

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[2] ACEEE calculation based on 2015 electricity and natural gas consumption and prices reported in EIA 2017a. For natural gas, we included all residential, commercial, and industrial sector consumption; we did not include electricity production, pipeline fuel, and natural gas production.

Most of the major players are primarily market-based and are not heavily regulated.[3] LDCs are an exception—they are generally a regulated monopoly, overseen by state utility regulators (in the case of investor-owned utilities) or city councils or cooperative boards (in the case of most publicly owned utilities).

Natural Gas Efficiency Trends

To evaluate long-term efficiency trends, we looked at national natural gas consumption per an appropriate unit for each sector. Figure 1 shows these trends. In general, normalized consumption increased until around the time of the 1973 energy crisis. Then (as we discuss later) consumption declined steeply until approximately 1985 when energy prices declined, and was level for about a decade thereafter. Consumption began declining again around 1995, particularly in the residential sector. The decline has been slightly less in the industrial sector, where inexpensive natural gas displaced other fuels, even as total energy consumption per dollar of shipments declined (Nadel, Elliott, and Langer 2015).

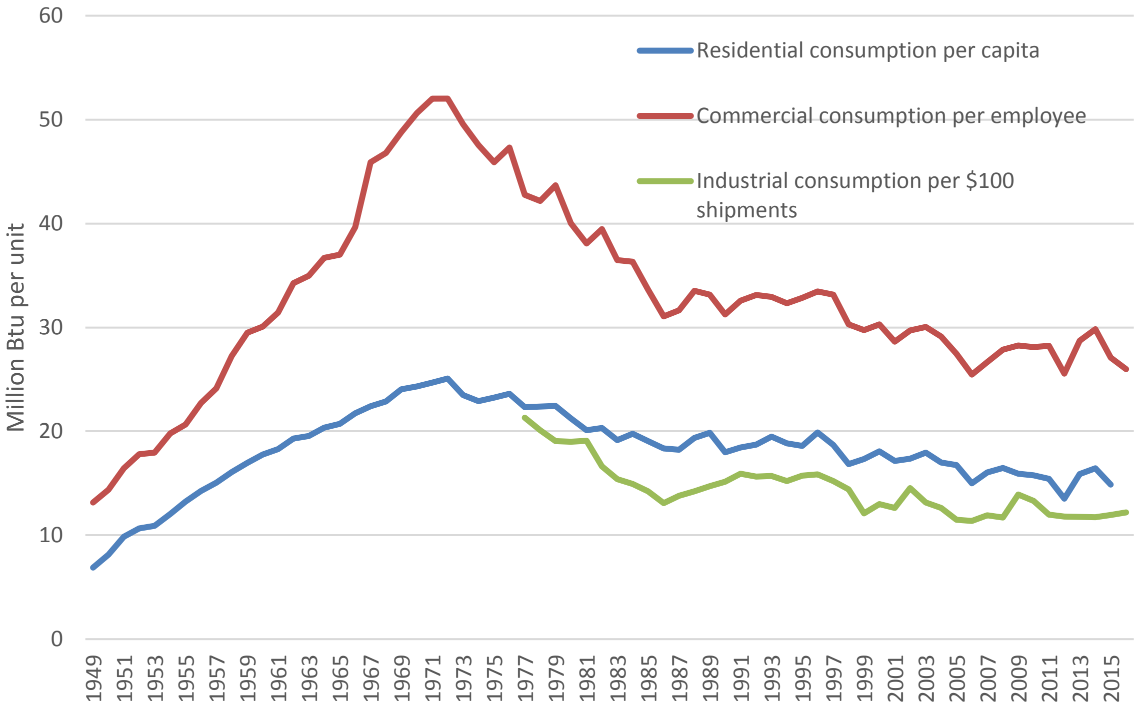

Figure 1. Normalized sectoral natural gas consumption, 1949-2016. Data are not adjusted for weather.
***Sources:* EIA 2017d for consumption and population, BLS 2017 for employees, FRED 2017 for industrial shipments.**

Contributors to Natural Gas Efficiency Progress

Many factors have likely contributed to progress in natural gas efficiency, but it is difficult to show direct cause and effect. Here, we discuss four major likely contributors. In the next

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[3] However the Federal Energy Regulatory Commission (FERC) does oversee interstate transmission charges.

section, we devote extra attention to a fifth contributor: utility-funded energy efficiency programs.

NEW TECHNOLOGIES

New, more efficient natural gas technologies continue to be developed, including:

- Condensing gas furnaces and boilers that condense water vapor in exhaust gases, recovering most of the heat
- More efficient clothes washers, dishwashers, showerheads, and faucets, which reduce hot water use
- More efficient water heaters, which improve combustion efficiency and reduce storage losses
- More efficient industrial processes, including the application of advanced sensors and controls for combustion processes and boilers

These developments are supported by public and private research and development (R&D), as well as by many of the policies discussed below. For example, R&D by the US Department of Energy (DOE) and the Gas Research Institute (GRI) contributed to the development of condensing furnaces (Broderick and Moore 2000). Utility and other programs have promoted these furnaces, and their market share has grown significantly, particularly in the northern half of the United States (see figure 2).

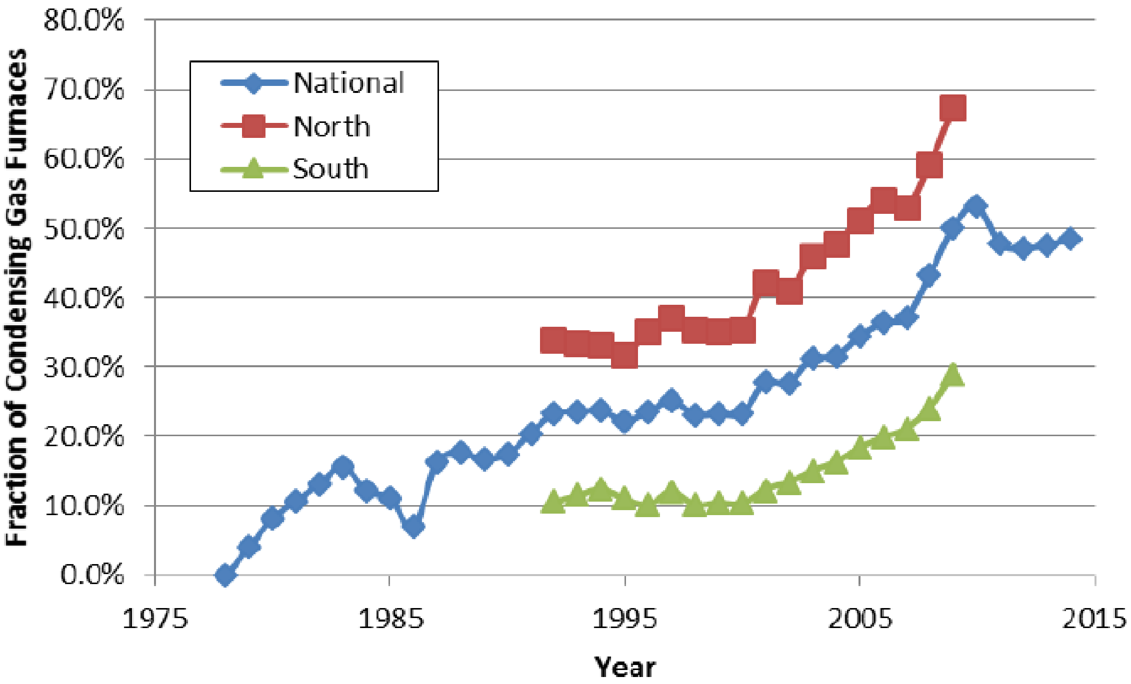

Figure 2. Fraction of US furnace shipments that are condensing, by year. The peak years were aided by federal tax incentives for condensing furnaces, which have since expired. *Source:* DOE 2016b.

PRICE EFFECTS

Natural gas prices are highly volatile. Figure 3 shows wellhead and residential real natural gas prices.[4] During the 1972–1984 period of rising prices, efficiency improvements accelerated, as shown in figure 1. However, despite rising prices from 2000 to 2008, efficiency gains were relatively limited during this period. On the other hand, when prices are low, such as in 1985–1995, efficiency improvements stagnated but did not revert to prior levels (see figure 1). For large customers, concerns about natural gas price volatility contribute to continued efficiency efforts even during periods of low prices. Large gas customers often hedge their natural gas prices, providing insurance against higher prices; this adds to the total, or *all-in cost*, of natural gas (Young, Elliott, and Kushler 2012). Many analysts believe that, due to plentiful supplies of shale gas, natural gas price volatility will be lower in the future than in the past (Manik and Petak 2017).

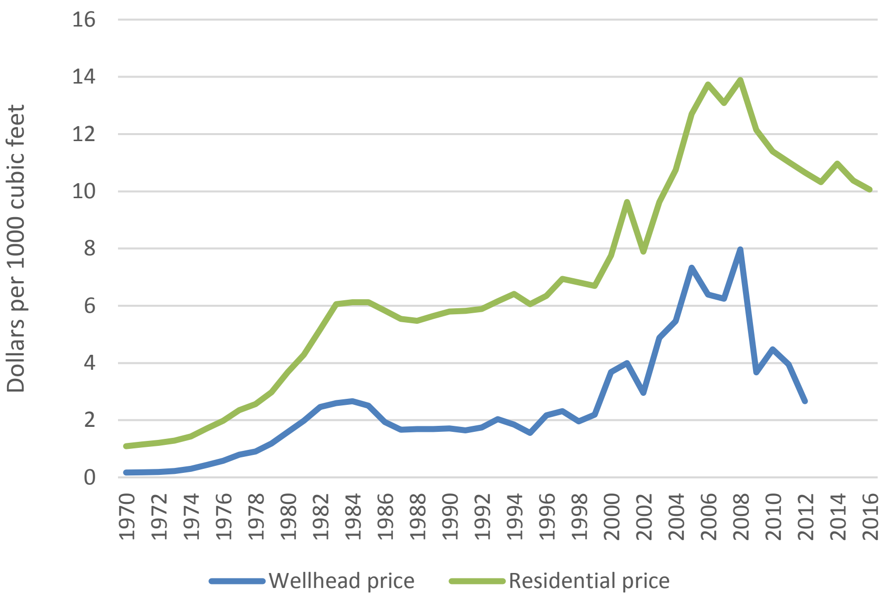

Figure 3. Real wellhead and residential natural gas prices (in 2015 dollars). Residential natural gas prices vary from region to region; some regions are higher and others are lower than the prices shown. ***Source:*** **EIA 2017c.**

BUILDING CODES

Since about 1980, state and local building codes have often regulated the energy efficiency of new construction. Generally, each state sets its own code, but these codes are often based on national model codes such as those developed for the International Energy Conservation Code (IECC, the leading residential code) and the American Society of Heating Refrigerating and Air-conditioning Engineers (ASHRAE, the leading commercial code).[5] DOE analyzes each edition of the model codes. In figure 4, we use these DOE data to plot

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[4] *Real* means in constant dollars and excluding the effects of inflation

[5] IECC also includes commercial codes, often based on the ASHRAE model commercial code, and ASHRAE is now working on a leading residential code for jurisdictions and builders that want to go beyond the IECC.

the energy consumption of a typical new home or commercial building that just meets a model code relative to the 1980 model code. These data combine electricity, natural gas, and other fuels.

As figure 4 shows, new compliant commercial building energy use is now nearly half of 1980 levels, while new home energy use meeting the model codes has declined nearly 40%. Pacific Northwest National Laboratory analyzed savings from building codes and estimated that the codes reduced US energy use by about 0.5 quadrillion Btu (quads) in 2012, and will save more than 2.2 quads in 2040 (Livingston et al. 2013). (PNNL does not provide data on natural gas savings alone; we provide the combined gas/electric number to indicate order of magnitude).

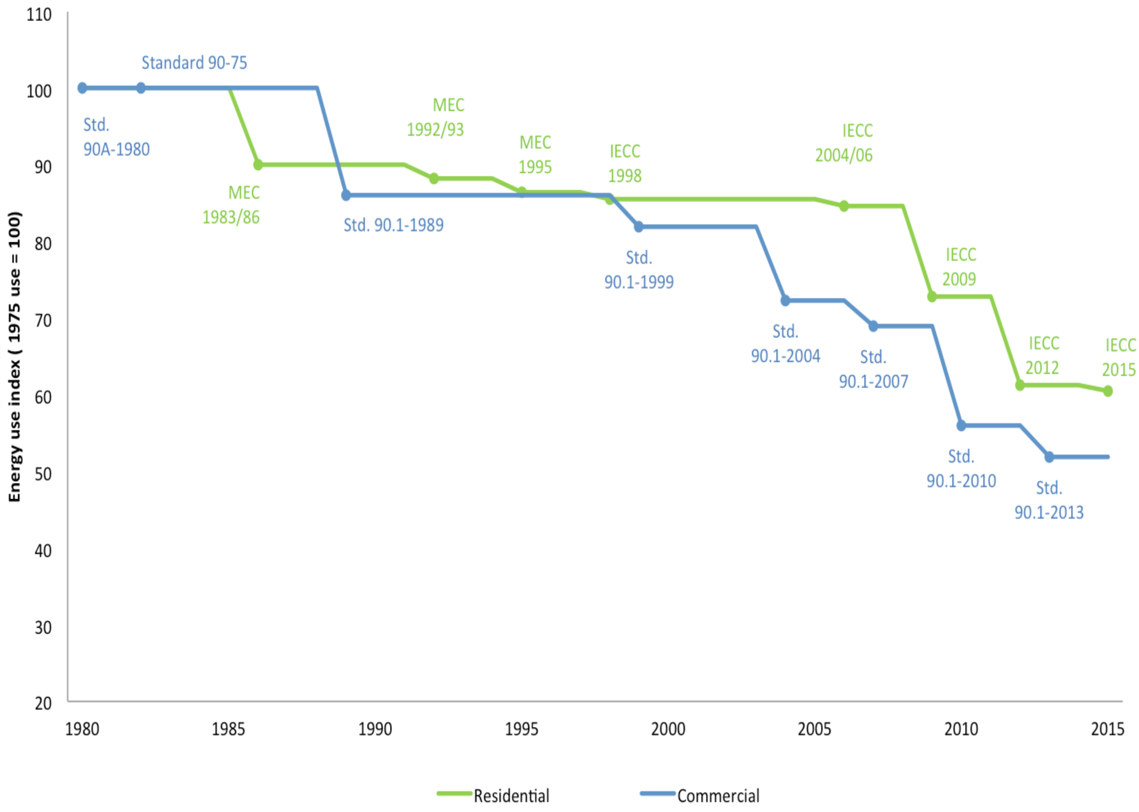

Figure 4. Energy consumption of new homes and commercial buildings meeting national model codes. A home or building just meeting the 1980 code has been normalized to an energy use index of 100. *Source:* ACEEE analysis using DOE data

APPLIANCE AND EQUIPMENT EFFICIENCY STANDARDS

States began adopting minimum energy efficiency requirements for various appliances and other energy-consuming equipment in the 1970s, and the first federal standards took effect in 1987. Currently, more than 50 products are regulated at the federal level. For natural gas, the major standards affect the energy efficiency of residential and commercial furnaces, boilers, and water heaters, and hot-water-consuming products such as clothes washers, dishwashers, showerheads, and faucets. The Appliance Standards Awareness Project (ASAP) tracks energy savings by year and fuel. Figure 5 shows savings for natural gas, propane, and fuel oil; the three fuels are combined in the ASAP data, but most of the savings are in natural gas. In 2015, these savings totaled about 4% of US natural gas, propane, and fuel oil consumption.

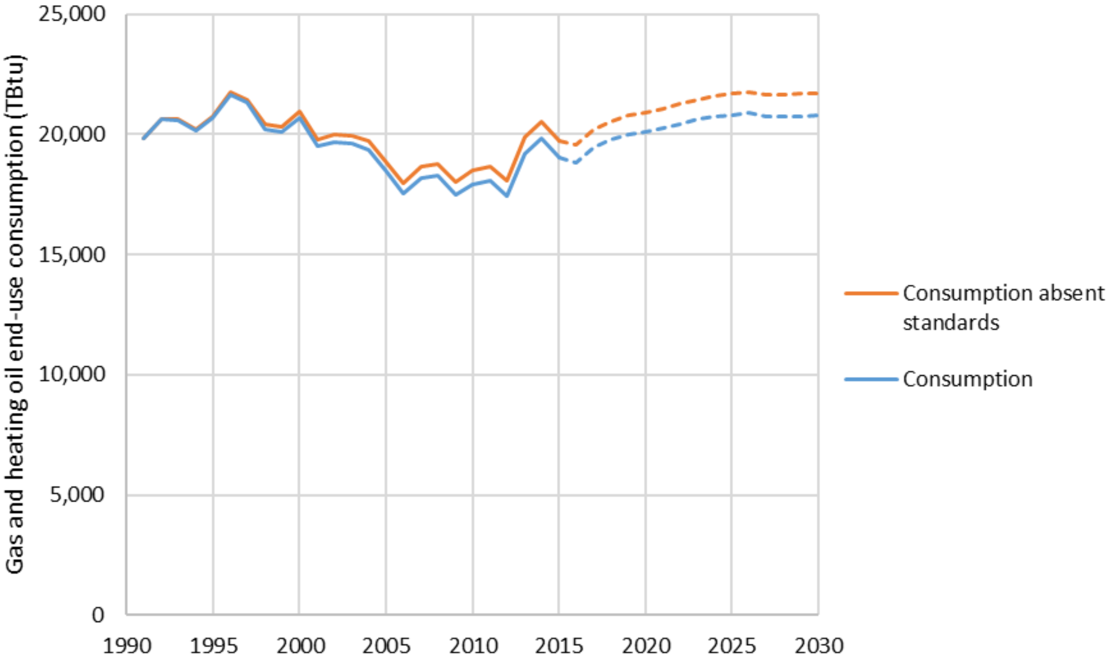

Figure 5. Fuel savings from appliance and equipment efficiency standards, 1991–2030. Savings are shown as the difference between the two lines. The savings from 2017–2030 include only standards that have already been finalized and reflect savings from replacing old appliances with products that meet current standards. *Source* for model and assumptions: deLaski and Mauer 2017.

Utility Energy Efficiency Programs

Since the late 1970s, many electric and gas utilities have operated programs to encourage and assist their customers in using energy efficiently. In some cases, utilities also fund programs operated by third-party organizations, such as the Energy Trust of Oregon and Focus on Energy in Wisconsin. ACEEE has tracked efficiency spending and savings for natural gas utilities since 2006.

SPENDING

Figure 6 shows utility energy efficiency spending trends. Natural gas utility energy efficiency spending has risen from about $0.3 billion in 2006 to about $1.4 billion in 2015. As the figure shows, electric utility energy efficiency spending is more than four times gas utility spending.

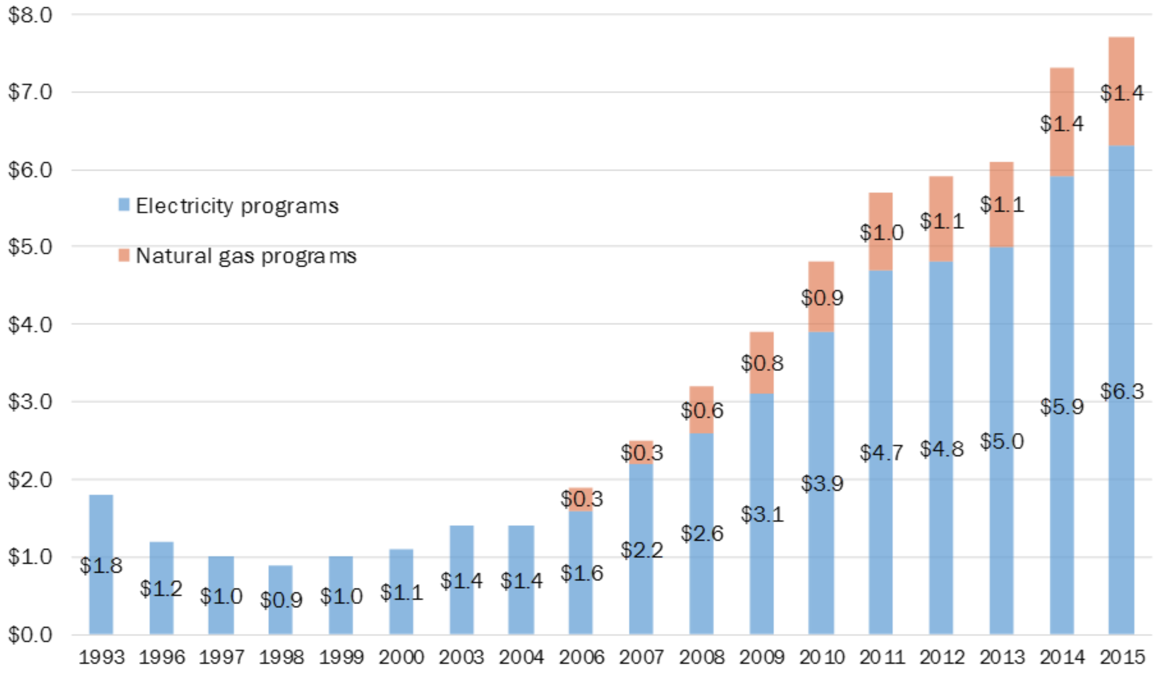

Figure 6. Utility energy efficiency spending by year ($billions). *Source:* Berg et al. 2016.

SAVINGS

Savings from programs funded by natural gas ratepayers have generally risen from year to year. We used two data sources to estimate efficiency savings, but the sources are not fully consistent with each other. For the period 2005–2009, we used data compiled by York et al. (2012) based on a survey of state utility regulators. However the data provided by the states are sometimes net savings (excluding savings that would have happened anyway) and sometimes gross savings (with no exclusion).[6] The 2011–2015 data are from the ACEEE *State Energy Efficiency Scorecard* reports for each year (e.g., Berg et al. 2016) and are more carefully screened and adjusted to include only net savings estimates. Both data sources include most states, but some states are missing, so the data should be considered indicative rather than absolute.

Figure 7 shows that savings have generally risen over time, albeit with periodic decreases as well. In recent years, incremental savings have been about 0.43% of residential and commercial natural gas consumption. However savings vary substantially from state to state and utility to utility.

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[6] The data for 2008 and 2009 reported in York et al. 2012 include some savings from measures installed in earlier years. We subtracted these savings from earlier years so that only incremental annual savings are included.

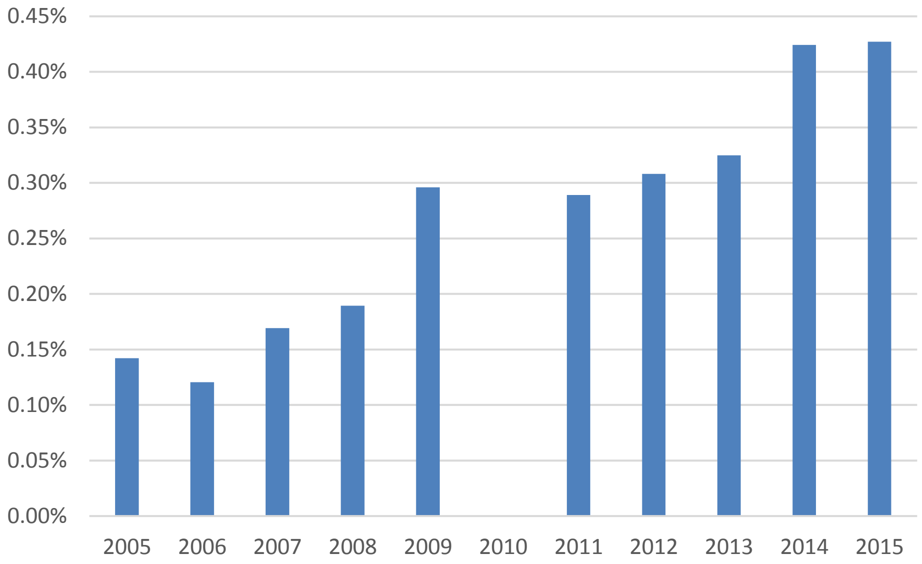

Figure 7. Net incremental savings from measures installed 2005–2015. These figures are approximate, as some states are missing in some years. Natural gas savings from York et al. 2012 (for 2005–2009) and the ACEEE *State Energy Efficiency Scorecard* reports for 2011–2015: Foster et al. 2012; Downs et al. 2013; Gilleo et al. 2014; Gilleo et al. 2015; Berg et al. 2016. Residential and commercial natural gas consumption from EIA 2017d.

Figure 8 illustrates incremental natural gas savings by state in 2015. Figure 9 summarizes 2015 savings as a percentage of sales for leading utilities. Each year, leading states and utilities are installing efficiency measures that save more than 1% of sales annually.

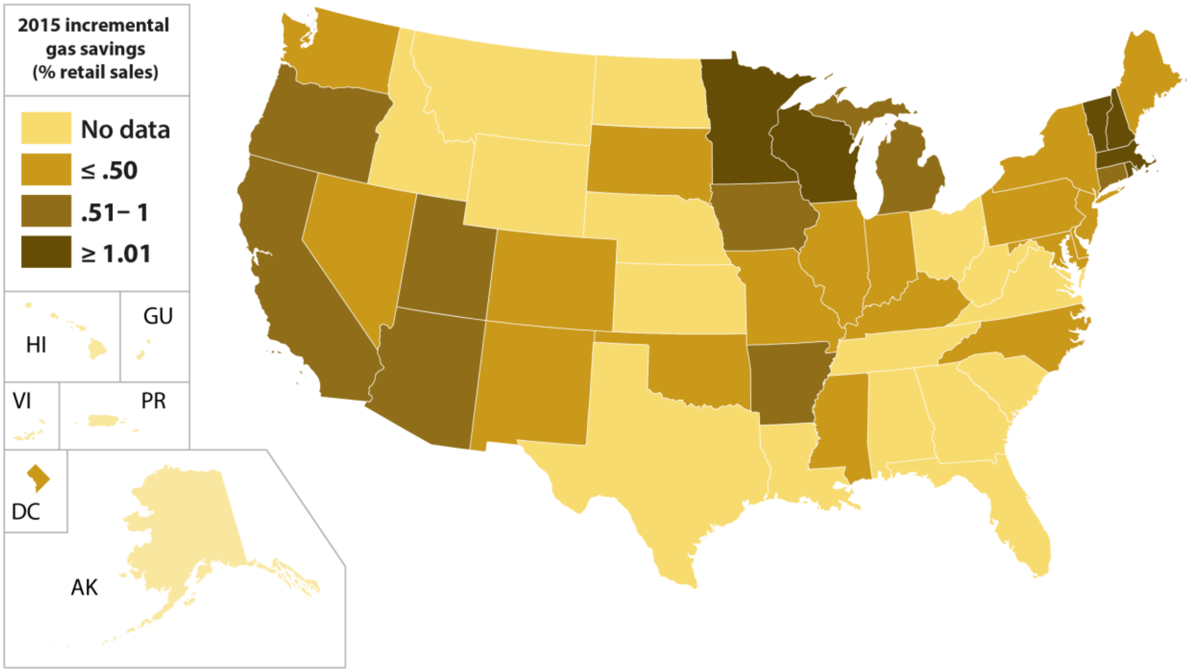

Figure 8. 2016 incremental gas savings from utility-funded programs by state. *Source:* Data from Berg et al. 2016. Data were obtained from state public utility commissions. Where data are missing, the state commission either could not or did not provide the data. States with missing data sometimes have no savings and sometimes achieved savings but did not provide data to ACEEE despite multiple requests.

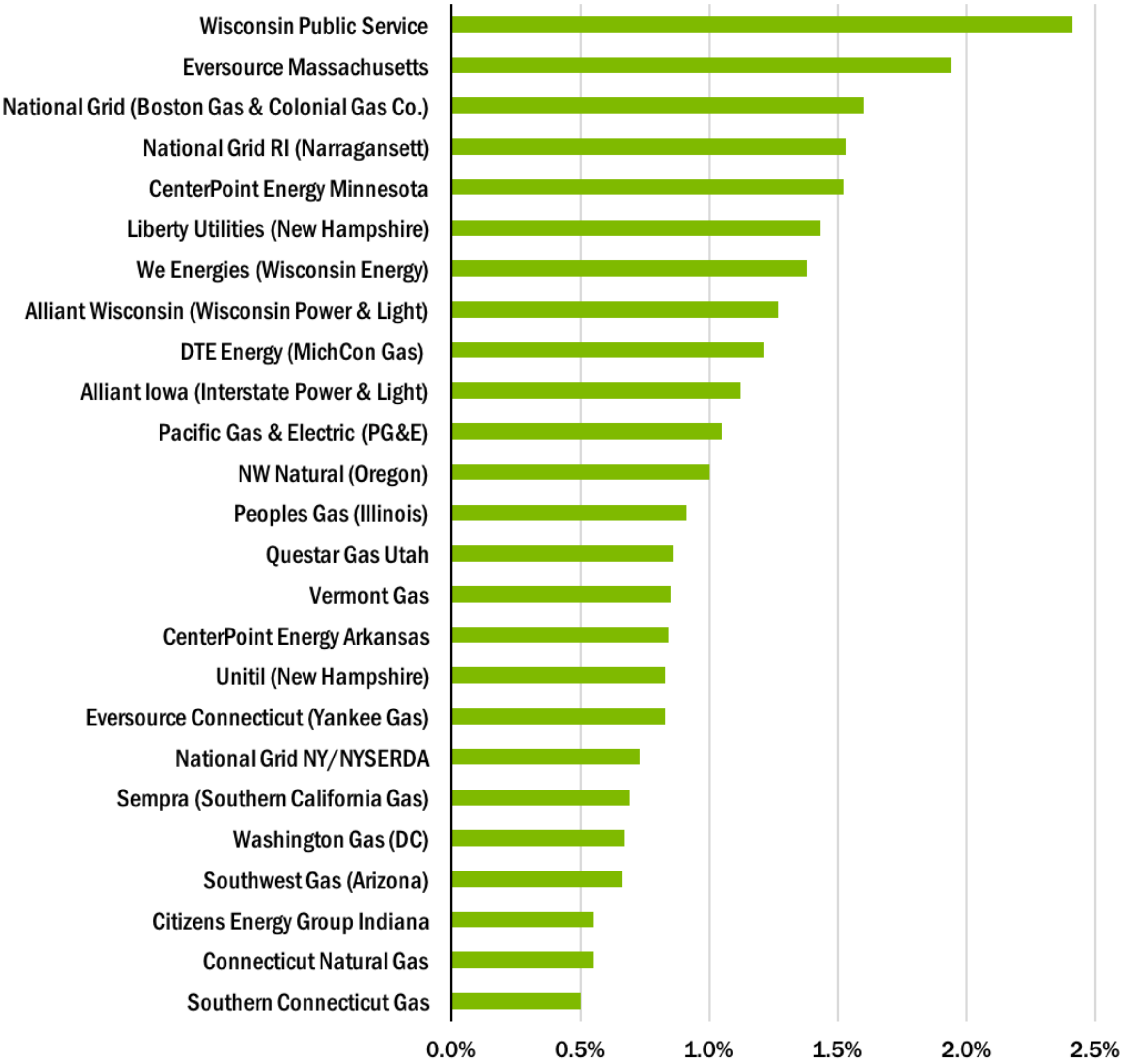

Figure 9. Incremental net savings by utility as a percentage of residential and commercial natural gas sales from leading utility-funded programs in 2015. Only utilities saving at least 0.5% of residential and commercial sales are shown. Where only gross savings are available, we estimate net savings at 86.4% of gross savings (from Berg et al. 2016). For conversions, we assume 1 CF = 1,037 Btu (EIA 2017d). A few other utilities likely also saved more than 0.5% of sales in 2015, but we were not able to obtain data from several utilities. *Source:* Ribeiro et al. 2017 for utilities serving major cities. Other utility savings data compiled from individual utilities for this report. Consumption from EIA 2016b.

Incremental savings from measures installed each year tell only part of the story, however. Table 1 shows our estimates of total natural gas savings by state in 2015 from measures installed in 2015, as well as measures installed in earlier years that are still in place and still saving energy in 2015. This table shows that, in states that have been implementing programs for many years, total 2015 natural gas savings are sometimes more than 5% of residential and commercial (R+C) natural gas sales.

Table 1. Estimated total 2015 natural gas savings from utility-funded programs

State	Savings as % of R+C sales
Vermont	6.4
Minnesota	5.7
Massachsetts	5.2
New Hampshire	5.0
Rhode Island	4.9
Michigan	4.4
Wisconsin	4.0
Oregon	3.6
Iowa	3.5
Arizona	2.8
California	2.7
Utah	2.6

Total savings include annualized savings from measures installed in 2015 plus 2015 savings from measures installed in earlier years that are still saving energy in 2015. Calculations assume a 16-year average measure life (from Molina 2014) and thus that about 3% of savings are lost each year (and therefore 50% of savings remain in Year 16, with some savings lost before Year 16 and some persisting after Year 16). *Source:* ACEEE analysis based on savings reported in the ACEEE *State Energy Efficiency Scorecard* reports since 2011 (citations listed under figure 7).

COST PER THERM OF NATURAL GAS SAVED

Molina (2014) looked at the savings and costs of natural gas utility programs over the 2009–2011 period. She found that, over this four-year period, programs cost the utility an average of 35 cents per therm (levelized cost). The costs per therm saved were essentially level over this period. Billingsley et al. (2014) arrived at very similar results for the same time period. More recent data have not been published.

MEASURES INCLUDED

Each utility emphasizes different efficiency measures. Northeast Energy Efficiency Partnerships has summarized data on savings by measure type for the Northeast (see figure 10). As the figure shows, more than half of the savings in New England are from residential and commercial building retrofits.

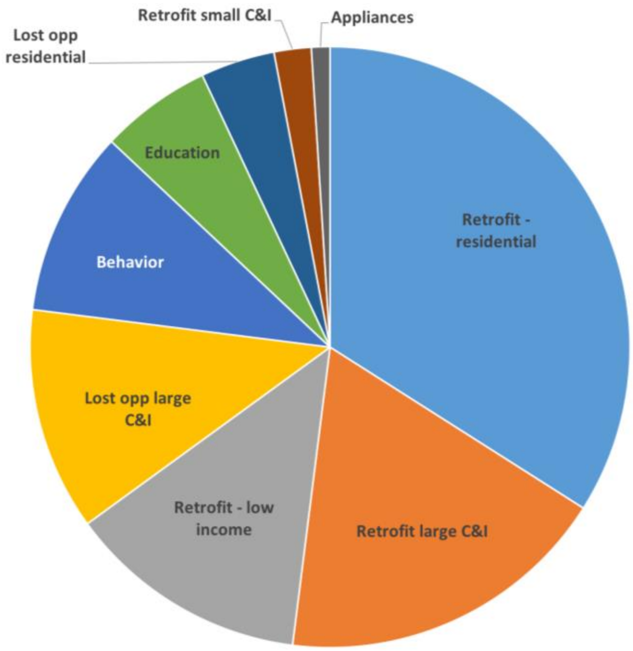

Figure 10. Natural gas savings for 2015 in energy units by measure type in the Northeast (Connecticut, District of Columbia, Delaware, Massachusetts, Maryland, New Hampshire, New York, Rhode Island, and Vermont). *Source:* NEEP REED database as contained in Caputo 2017.

THE ROLE OF ENERGY EFFICIENCY RESOURCE STANDARDS

One of the major contributors to utilities achieving substantial savings are mandatory energy savings targets, or *energy efficiency resource standards* (EERS), which are set by state legislatures or utility commissions. As of this writing, 17 states have EERS requirements for natural gas savings. Figure 11 shows these 17 states; of the high-savings states shown in figure 8, only Utah does not have an EERS.

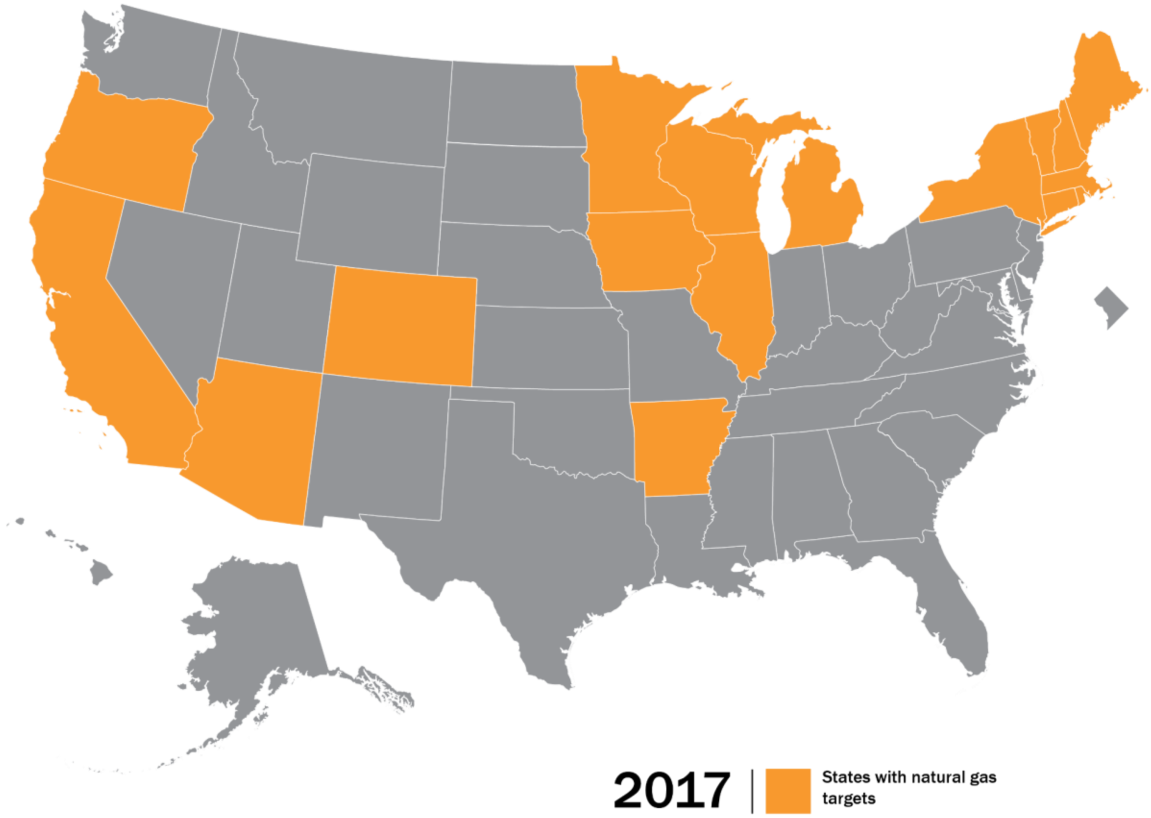

Figure 11. States with natural gas EERS targets. *Source:* Berg et al. 2016.

Molina and Kushler (2015) demonstrated that EERS targets, as well as decoupling and incentives (explained below), have a positive impact on energy efficiency savings. Table 2 updates this analysis with a focus on natural gas energy efficiency spending and savings in 2015 for the 17 states with a gas EERS and the 33 states without a gas EERS. Spending and savings are nearly a factor of 10 higher in the EERS states, indicating that the standards are likely having substantial influence.

Table 2. Comparison of states with and without a natural gas EERS

Policy	No. of states	Average EE investment per residential customer	Average EE savings as % of R+C sales*
No EERS	33	$4	0.08%
EERS	17	$33	0.82%

* Includes only the 33 states that provided data.
Source: ACEEE analysis based on data in Berg et al. 2016.

DECOUPLING AND INCENTIVES

Another important contributor to utility interest in energy efficiency programs is whether regulators have provided a business case for energy efficiency investments. Traditionally, utilities generally made more money by selling more gas and investing more in infrastructure, earning a rate of return on these investments. To establish a utility business case for energy efficiency, regulators commonly use two mechanisms.

First, utility profits can be decoupled from sales by adjusting fixed cost recovery to reflect actual sales. In this way, a utility fully recovers its fixed costs if sales are less than expected but does not receive excess fixed cost recovery if sales exceed expectations. Second, regulators can provide utility shareholders a performance incentive for meeting or exceeding energy efficiency goals.

As figure 12 shows, in 2015, natural gas utilities in 29 states had decoupling and/or performance incentives for shareholders, up from 20 states in 2008 (Eldridge et al. 2008). Some other states address the fixed cost recovery issue with lost revenue recovery mechanisms (reimbursing utilities for the fixed costs associated with energy efficiency program savings, regardless of other contributors to higher or lower sales) or straight fixed variable rates (increased fixed charges to reduce the potential for lost revenues). Neither of these other mechanisms are shown in figure 12.

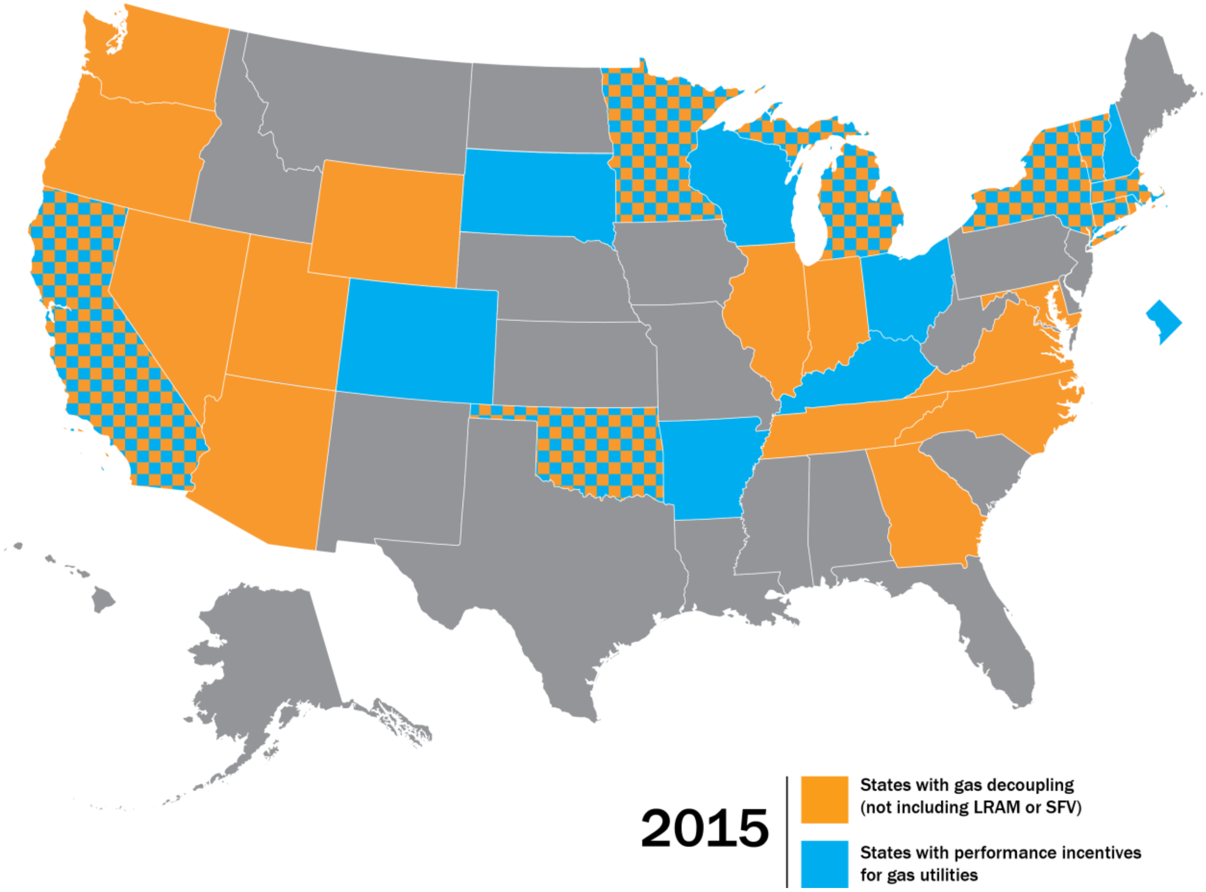

Figure 12. States with decoupling or performance incentives for gas utilities in 2015. Checkered states have both decoupling and performance incentives. Decoupling states do not include states with lost revenue adjustment mechanisms (LRAM) or with straight fixed variable (SFV) rates. *Source:* Data from Berg et al. 2016.

The Future

PROJECTED NATURAL GAS CONSUMPTION

Although natural gas efficiency savings have increased over time, in recent years, natural gas consumption has been increasing and is projected to continue to grow through 2040 (see figure 13). Increasing consumption is primarily in the electric power and industrial sectors, with residential and commercial consumption essentially level, despite growth in the number of customers (i.e., growth in the number of customers is offset by declining use per customer). Transportation consumption is small but growing. EIA (2017a) projects that these trends will continue, with growth primarily in the industrial sector; consumption for electric power generation will level off in the 2020s and grow again in the 2030s. The increase in industrial sector consumption appears to be due to greater natural gas use in three areas: (1) as an industrial feedstock (raw material), (2) for power generation within industry, and (3) for gas used within the natural gas industry as gas production grows. The leveling of natural gas use in the power sector appears to be due both to higher natural gas prices that allow existing coal plants to operate for more hours and to growing renewable energy generation.

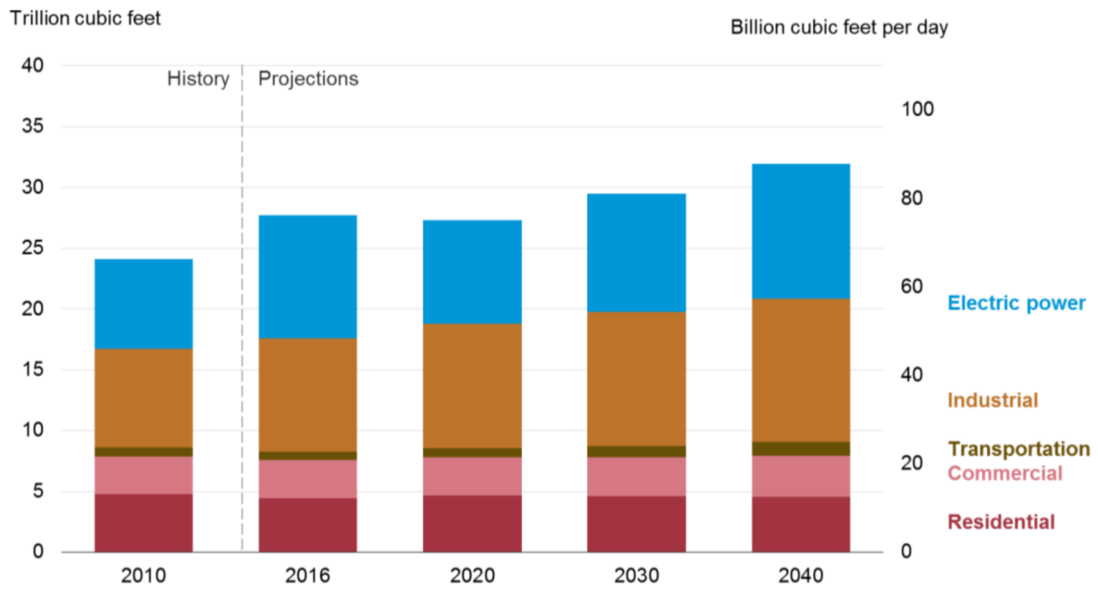

Figure 13. Natural gas consumption by sector. *Source:* EIA 2017a.

EFFICIENCY OPPORTUNITIES

While energy efficiency has reduced natural gas use significantly, large opportunities for cost-effective savings remain. Neubauer (2014) reviewed a wide array of energy efficiency potential studies, including 18 that provided natural gas savings estimates that were both economic and achievable over different time periods. He distilled these estimates into an annual rate of natural gas efficiency improvement. Across the 18 studies, maximum achievable potential ranged from 0.5 to 2.4% per year, with a median value of 1.0% per year and an average value of 1.1% per year.

Recent Studies

For this report, we looked at three more recent studies, compiled by consulting firms for three utilities in three states (Arkansas, Michigan, and Washington). As figures 14 and 15 illustrate, the studies' results are generally consistent with past studies, showing an economic and achievable efficiency potential of approximately 1% per year. These recent studies show that, despite the current low price of natural gas, substantial cost-effective natural gas savings are still possible. The reason for this is that many efficiency measures profiled in these recent studies cost less per cubic foot of gas than the current price of natural gas.

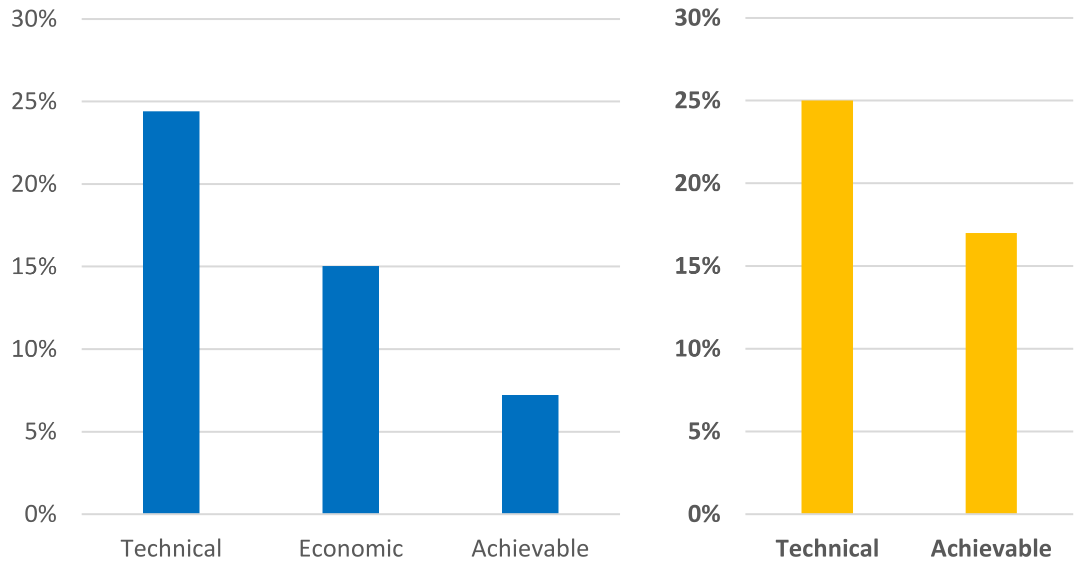

Figure 14. Available savings as percentage of sales from recent natural gas efficiency studies prepared for Arkansas Public Service Commission (left: Arkansas Public Service Commission 2015) and Puget Sound Energy (right: Cadmus 2015). *Technical potential* denotes what is technically possible without considering economics. *Economic potential* includes only measures that are cost effective per the methodology used in each study. *Achievable potential* estimates the portion of the economic potential that can be achieved using participation rates estimated by the study authors. The Arkansas study covers a 10-year implementation period, the Puget Sound study a 20-year implementation period. With an extra 10 years, more savings are achievable in the Puget Sound study than the Arkansas study.

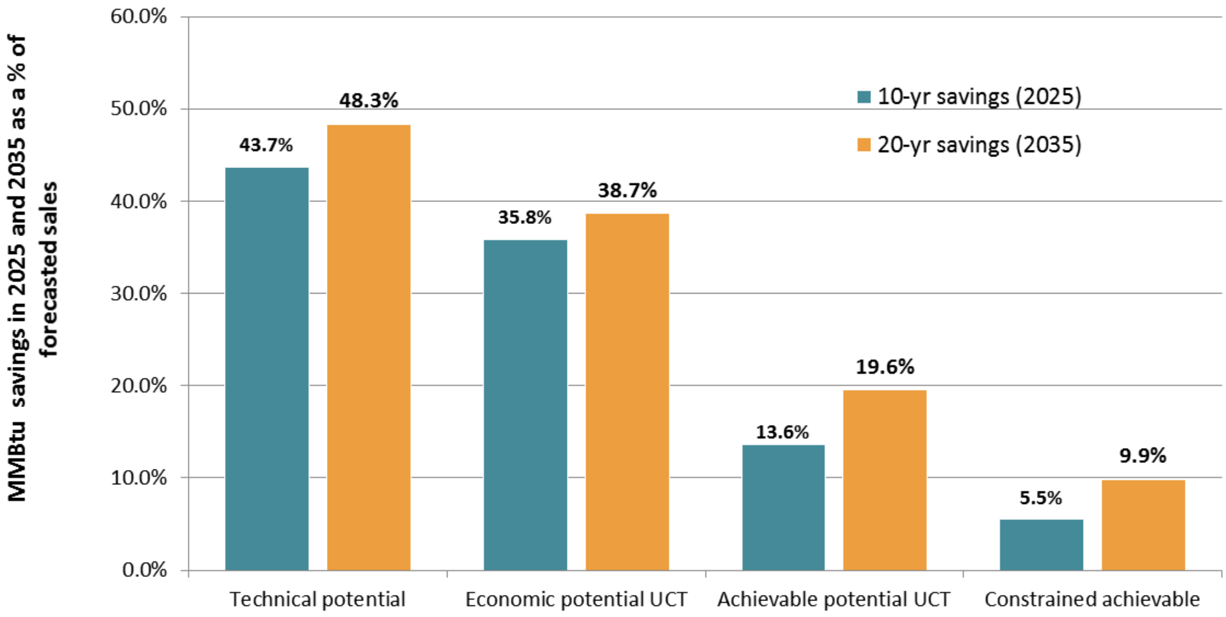

Figure 15. Available savings from a recent natural gas efficiency study prepared for Detroit Edison (DTE Energy 2016). This study looks at efficiency measures that can be implemented over both 10- and 20-year periods.

We also looked at the efficiency measures with the largest energy savings in each of these studies. Table 3 summarizes these results. Each of the studies were conducted by different firms and look at different measures. Generally, however, residential space heating and weatherization measures are most common, followed by commercial space heating, control and envelope measures, and residential water heating measures. Industrial measures are also significant in the Puget Sound and Arkansas studies. Quite a few of these measures save electricity as well as natural gas, assisting with the measures' cost effectiveness.

Table 3. Top 10 efficiency measures from each study, ordered from lowest to highest

Detroit Edison	Puget Sound Energy	Arkansas
Res. furnaces	Res. heating	Res. ceiling insulation
Res. windows	Comm. heating	C&I steam trap replacement
Res. air sealing	Res. water heat	C&I boiler burner replacement
Comm. space heating	Comm. water heat	Res. wall insulation
Comm. HVAC controls	Comm. cooking	Res. furnace replacement
Res. shower/faucet	Ind. process	Res. air infiltration
Res. insulation	Comm. pool heat	Res. showerheads
Res. thermostat	Ind. HVAC	C&I high-effic. boiler
Comm. envelope	Ind. indirect boiler	C&I steam cooker
Res. boiler	Res. cooking	Res. tankless water heater

For Detroit Edison, we used economic potential; for Puget Sound Energy, we used achievable potential; and for Arkansas, we used the 2025 achievable potential. *Sources:* Arkansas Public Service Commission 2015; Garth et al. 2015; DTE Energy 2016.

A National Estimate

To complement these individual utility and state studies' results, we also prepared an approximate estimate for the nation as a whole, using available national data such as from EIA's A*nnual Energy Outlook 2017* (EIA 2017a). Our estimate is a technical potential estimate including measures that are generally cost effective. We prepared this analysis to show the distribution of major efficiency opportunities, rather than a precise estimate of the overall savings potential. The key calculations, data sources, and assumptions we used to prepare these estimates are summarized in the Appendix. Figure 16 shows the results: the largest natural gas efficiency opportunities are in the industrial sector—not surprising, given that approximately half of end-use natural gas consumption is at the industrial level (EIA 2017a).[7] The next largest savings opportunities are in residential and commercial building retrofits, smart commercial building measures (such as enhanced sensors and controls), commercial new construction, and residential water heating and thermostats.

Our analysis covers new construction and equipment replacement through 2030. We find a savings potential of approximately 26%, which works out to about 2% per year. A significant share of the savings will not be achievable because not all customers can be convinced to implement all cost-effective measures. If half of the savings are achievable, our results are similar to those of the other studies summarized above (e.g., an achievable savings potential of about 1% of sales each year).

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[7] In this calculation, we include end-use consumption in the residential, commercial, industrial, and transportation sectors, but do not include gas used in large electric generation plants or in oil and gas industry field operations.

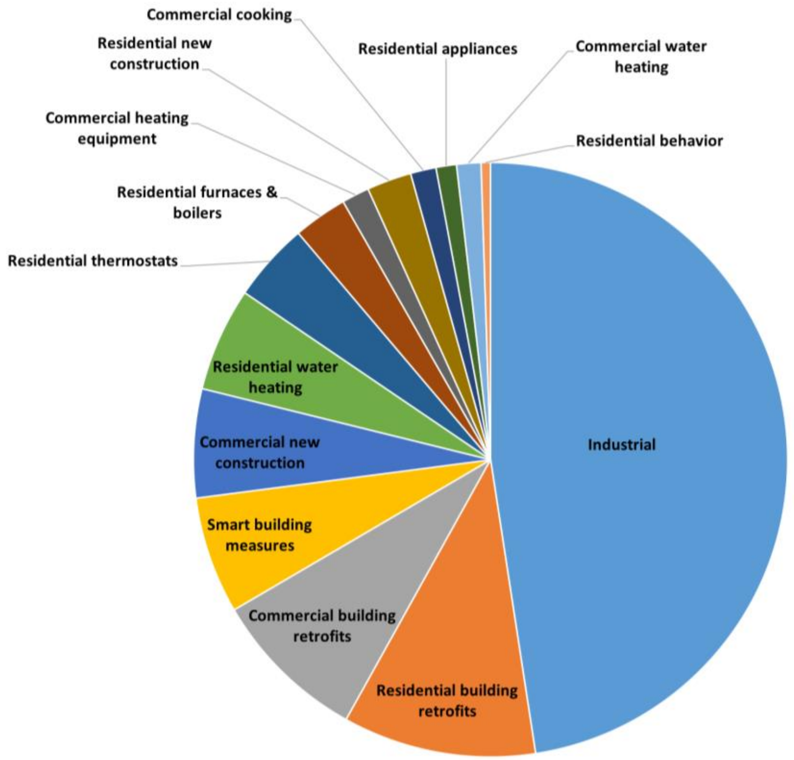

Figure 16. Contribution of various efficiency measures to natural gas technical/economic savings potential. Key calculations, data, and assumptions are summarized in the Appendix of this report. *Source:* ACEEE analysis.

Other Current Issues and Opportunities

A variety of other issues related to energy efficiency opportunities and the natural gas industry's evolution are worth noting and discussing. Here, we focus on four of these issues: CHP, transportation fuels, coordination between natural gas and other utilities, and electrification.

COMBINED HEAT AND POWER

CHP is the most energy-efficient method of generating power available today. CHP reduces gas use to the extent that it displaces more conventional gas generation.

Opportunity

Natural gas CHP systems can have efficiencies of 80% or more, much better than the approximately 45% average annual efficiency of gas combined-cycle plants (EIA 2016a).[8] CHP systems obtain these efficiencies by using waste heat to provide heat for industrial processes, space and water heating, and even air-conditioning (using absorption cooling

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[8] The average operating heat rate in 2015 for natural gas electric power plants was 7,878 Btu/kWh or an efficiency of 43%. See EIA 2016a, table 8.1. (3,412/7,878 = 43%)

technologies).[9] We chose not to include CHP in figure 14 because much of the energy savings are in power generation, although at the end-user level, waste heat and onsite electric generation offers substantial benefits, including cheaper heating and electricity, and the reliability benefits of having power generation on-site. In part because of these reliability benefits, it is becoming more common for critical facilities such as hospitals to install CHP systems (Hampson et al. 2013).

Approximately 83 GW of CHP capacity are in operation today. In the industrial sector, CHP consumed about 1,300 trillion Btu of natural gas in 2016, along with smaller amounts of other fuels (EIA 2017d). If conventional natural gas plants are displaced by CHP systems that have twice the efficiency, then the gas savings in 2016 amounted to roughly 1,500 trillion Btu—that is, 1,300 in the industrial sector, plus roughly 15% more for other sectors (based on Kelly 2016).

Significant additional potential—an estimated 149 GW—remains in untapped onsite technical potential at more than 290,000 sites in the United States (DOE 2016a). However technical potential is an estimation of market size constrained only by technological limits; it does not address economic or other factors that influence consumer adoption of CHP. Based on studies prepared by ICF International for the American Gas Association (AGA) and for DOE, we estimate that approximately 47 GW of CHP could have a payback period of under 10 years.[10] This implies that the natural gas savings from CHP use could increase by more than 50% (i.e., the 47 GW of potential is 57% of the current 83 GW of capacity).

Utility Ownership

CHP has not been implemented in attractive sites for many reasons, including economic and financial barriers, regulatory barriers, and information barriers (DOE 2015a). One way to overcome some of these barriers is to allow and even encourage electric and gas utilities to develop CHP systems at appropriate sites. The utilities have expertise in power systems that most customers do not; they also have a low cost of capital. Further, utilities should be able to earn their authorized rate of return on CHP systems determined to be in the public interest including systems that provide needed power at high efficiency and/or systems needed for reliability purposes, such as at hospitals and other critical facilities. Some utilities already own and operate CHP systems at customer sites. Kelly (2017) has identified 149 such systems with a total generation capacity of about 3,600 MW. Examples include:

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[9] The DOE covers the basics of absorption cooling at energy.gov/eere/energybasics/articles/absorption-cooling-basics.

[10] In 2013, ICF International and the AGA modeled CHP's technical potential in every state and sorted results into three bins based on simple payback: less than 5 years, 5–10 years, and more than 10 years. The study found that approximately 42 GW of potential would have a simple payback of less than 10 years (Hedman, Hampson, and Darrow 2013). The 47 GW estimate is based on the ICF 2016 technical potential estimate for DOE (DOE 2016a) times the ratio of economic to technical potential identified in the 2013 ICF/AGA study (Hedman, Hampson, and Darrow 2013).

- Austin Energy has a 4.3 MW system at the Texas Medical Center (DOE 2015c).
- Florida Public Utilities/Chesapeake Public Utilities have a 21.7 MW system at Rayonier Advanced Materials in Fernandina Beach, Florida (Chesapeake Utilities 2016).

In addition, several utilities have announced plans to help develop CHP systems:

- Duke Energy proposed the development of several CHP systems, including systems at Duke University and Clemson University (DEC 2016; DEC 2017).
- In 2015, Southern California Gas received approval from the California Public Utilities Commission to offer a Distributed Energy Resource Service Tariff including a fully optional, nondiscriminatory, vendor neutral, shareholder funded program that allows SoCalGas to design, construct, own, operate, and maintain CHP or waste-heat-to-power equipment on a customer's premises. The customer pays a monthly fee for the service, is responsible for providing fuel to the system, and takes ownership of all energy outputs (Southern California Gas 2017; CPUC 2015).

TRANSPORTATION FUELS AND ENERGY EFFICIENCY

Natural gas can be used as a transportation fuel, either as CNG or LNG. The natural gas industry and its allies have often suggested expanding this role (e.g., NPC 2012; GTI 2013). Natural gas engines are spark-ignited, similar to gasoline engines, and they have similar efficiencies. Thus, burning natural gas in an engine is generally neither more nor less efficient than burning gasoline or diesel fuel. However, because natural gas vehicles often compete with high-efficiency electric and hybrid-electric vehicles for a share of the advanced vehicle market, we briefly discuss transportation options here.

Natural gas can be used in some transportation applications to reduce costs or emissions. In terms of costs, natural gas in 2015 cost transportation customers approximately $16.32 per million Btu. By comparison, the cost of gasoline or diesel in 2015 was about $21.16 and $20.06 per million Btu, respectively (EIA 2017a, table 3). Thus, at current fuel prices, natural gas is less expensive, although converting an engine to run on natural gas is costly and there is no guarantee that the current fuel price disparity will continue.

In terms of engine emissions of major criteria pollutants, natural gas vehicles are generally cleaner than gasoline or diesel vehicles. In the case of light-duty vehicles, however, increasingly strict, fuel-neutral tailpipe standards ("Tier 3") limit these differences for compliant vehicles. For heavy-duty vehicles, natural gas engines offer low NOx emissions without the expensive emissions control devices required for diesel engines. Tailpipe greenhouse gas emissions from natural gas vehicles are lower as well and can be reduced further using renewable natural gas, but this benefit is offset to varying degrees by methane leakage at various fuel cycle stages. Energy use and emissions of battery electric vehicles can be lower than natural gas vehicles (Wang and Elgowainy 2014).

In the light-duty market, natural gas offerings are very limited. For many years, Honda offered car buyers a natural gas option. However sales were low and the model was discontinued in 2015 (Kanellos 2016). Fleet buyers can still contract for natural gas vehicles or convert gasoline vehicles. Such purchases might make sense if there is a nearby refueling station, or if the fleet is large enough for its own natural gas refueling facility. However the relatively low density of CNG limits the range of vehicles that use it, so the vehicles generally must travel within the range of a refueling station (Minton 2015). Another factor is how many miles each vehicle travels: if the distance they travel is insufficient, the fuel cost savings will not offset the higher cost of natural gas vehicles. In the long-run, natural gas vehicles will likely compete against electric vehicles—a competition that at least one observer has found in favor of electric vehicles after considering the various factors important to typical consumers (Kanellos 2016).

For heavy-duty vehicles, electric vehicles are regarded as infeasible in many applications due to battery requirements,[11] and natural gas can be less expensive than conventional fuels. CNG has been used for heavy-duty pickup trucks and vans and can make sense for fleets with nearby refueling and with vehicles that typically go out and back. In such cases, while there are obviously costs, there also may be long-term savings (Minton 2015). As an illustration, FedEx uses CNG for some of its vehicles, but finds that they cost 50–80% more than conventional vehicles and therefore uses them only in cities with plenty of fueling options (Holeywell 2014).

In the medium-duty market, hybrid- and fully electric vehicles will provide competition, particularly for applications with considerable stop and go (in these applications, the regenerative braking capability of these vehicles adds to fuel economy).[12] For many applications, the competition between natural gas vehicles and electric vehicles will play out over time. For example, an analysis for the Los Angeles Metro system found that CNG buses make sense today and that use of renewable natural gas and low NOx engines can be phased in over the next few years, but that by 2025, electric buses might make the most sense (Lowell et al. 2016). Refuse haulers may be another good market for CNG vehicles (Laughlin and Burnham 2014). To provide a decent economic return, vehicles may need to be used for many miles (Holeywell 2014) and flex-fuel vehicles need to use natural gas most of the time (Minton 2015).

For long-haul trucks, LNG is preferred over CNG due to the vehicles' much longer range between refueling. The keys to the future for natural gas here will be developing a national refueling infrastructure for LNG at truck stops and the price of natural gas relative to diesel fuel.

In sum, opportunities for natural gas vehicles appear to be modest, limited to some fleets and applications.

COORDINATION BETWEEN GAS, ELECTRIC, AND WATER UTILITIES

As discussed above, a substantial amount of remaining efficiency opportunity involves insulation and other improvements in residential and commercial buildings. Many of these buildings might use natural gas for space heating but electricity for air-conditioning.

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[11] Tesla has recently challenged this notion. See www.wired.com/2017/04/tesla-electric-truck/.

[12] A hybrid-electric vehicle could be designed to run on natural gas, but would be more expensive.

Likewise, appliances such as clothes washers use electricity to power the appliance and gas to heat the water they use.

Marketing energy efficiency to residential and small commercial customers is expensive. To maximize energy savings and economic benefits, it makes sense for gas and electric utilities to work together, sharing costs for marketing and for measures that save electricity, gas, and water. Nowak, Kushler, and Witte (2014) discuss examples of good cooperation between natural gas and electric utilities. Young (2013) discusses examples of cooperation between energy and water utilities. In both cases, the authors note the many advantages of cooperation and coordination. A particularly illustrative example is provided by a joint $440 million effort involving nine programs operated by the Los Angeles Department of Water and Power (the electric and water utility) and Southern California Gas (the gas utility) (Drake et al. 2014). Gas, electric, and water utilities should build on these examples going forward.

FUEL SWITCHING

Electrifying various end-uses over multiple decades to reduce emissions is an approach gaining increased attention (CCST 2011; Howland et al. 2014; Dennis 2015). Natural gas has lower emissions than other fossil fuels, and it is presently lower in price. Thus, for the time being, most electrification efforts are focusing on displacing oil and propane, including for vehicles and space and water heating. In the long-term, however, emissions from electricity might be lower than from non-renewable natural gas if electricity is primarily generated from renewable and nuclear energy or other zero- or near-zero emissions sources (e.g., plants with carbon capture).[13]

In 2016, ACEEE examined the energy use (and by extension, the emissions)[14] and economics of gas furnaces versus electric heat pumps (Nadel 2016). The key findings of this study can be summarized in two figures. First, figure 17 looks at the relative energy use of a condensing gas furnace and a conventional ENERGY STAR® certified heat pump. The heat pump generally does better in the south, the furnace in the north. But new technologies can change this comparison in the north, with cold climate electric heat pumps (optimized for operation at low temperatures) generally having lower energy use than condensing furnaces, but gas heat pumps (driven by gas instead of electricity) often outperforming the cold climate heat pumps (the cold climate heat pump and gas heat pump comparisons are not shown in figure 17).[15]

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[13] Note that some natural gas can be produced from renewable feedstocks; see E3 2015.

[14] Lower energy use results in lower emissions given the study's assumption that power for heat pumps would generally come from plants fueled by natural gas.

[15] There are also somewhat similar options for water heating, with condensing gas water heaters, electric heat pump water heaters, and even gas heat pump water heaters (now in development; see Glanville, Vanal, and Garrabrant 2016) available as replacement options for electric resistance or conventional natural gas or propane storage water heaters. Also, in addition to energy use, emissions, and economic issues, there are load shape issues associated with electrification. For summer-peaking utilities, there may be extra system capacity to handle winter loads from new heat pump installations, but for winter-peaking utilities, additional heat pumps will

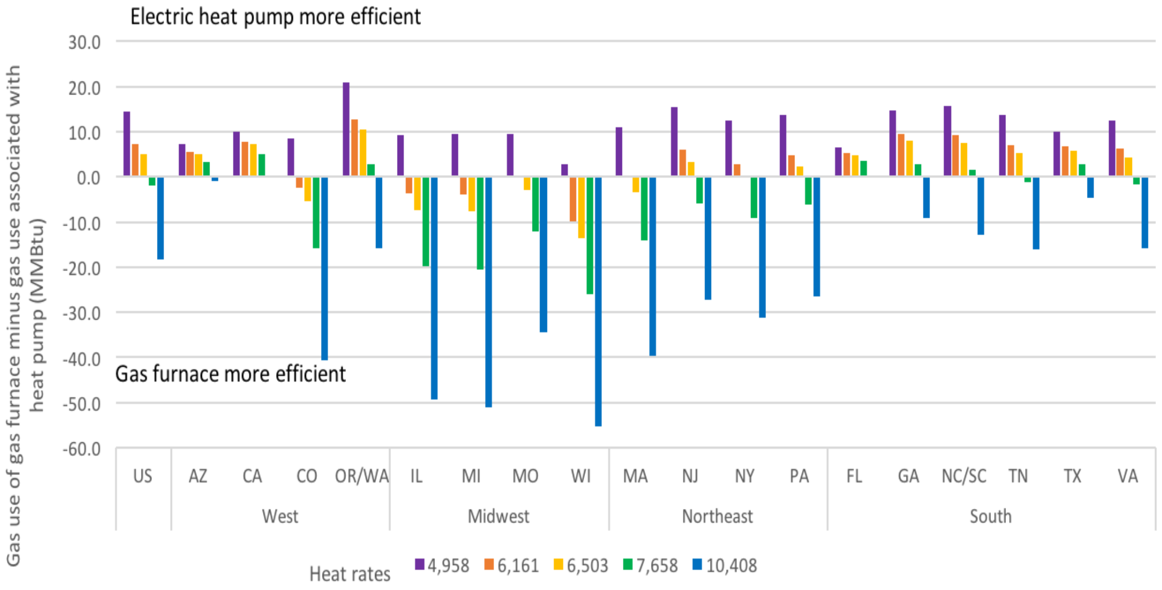

Figure 17. Comparison of the energy use of a 95% efficient condensing gas furnace with a heat pump with an efficiency of 8.5 (expressed in terms of heating season performance factor or HSPF). The various bars are for different heat rates for converting natural gas to electricity, ranging from 4,958 Btu per kWh (for a state-of-the-art combined-cycle system in a grid also using extensive renewable energy) to 10,408 Btu per kWh (for a conventional steam turbine). The in-between heat rates are for various combined-cycle plants. *Source:* Nadel 2016.

Second, figure 18 looks at the relative economics of gas furnaces and electric heat pumps. This considers the economics of replacing an existing central air conditioner with a central heat pump when the air conditioner fails and must be replaced. At current electric and natural gas rates, the electric heat pump often does a little better in the South and some western states, while the gas furnace does better in the Northeast and Midwest. Figure 18 does not include cold climate and gas heat pumps because not enough is yet known about their cost.[16]

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generally add to the winter peak, which typically occurs in the early morning before significant power from solar systems is available.

[16] Based on off-the-record discussions with a manufacturer who is working on gas heat pumps, absent unanticipated major breakthroughs, the cost of such systems is likely to be substantial and the economics challenging.

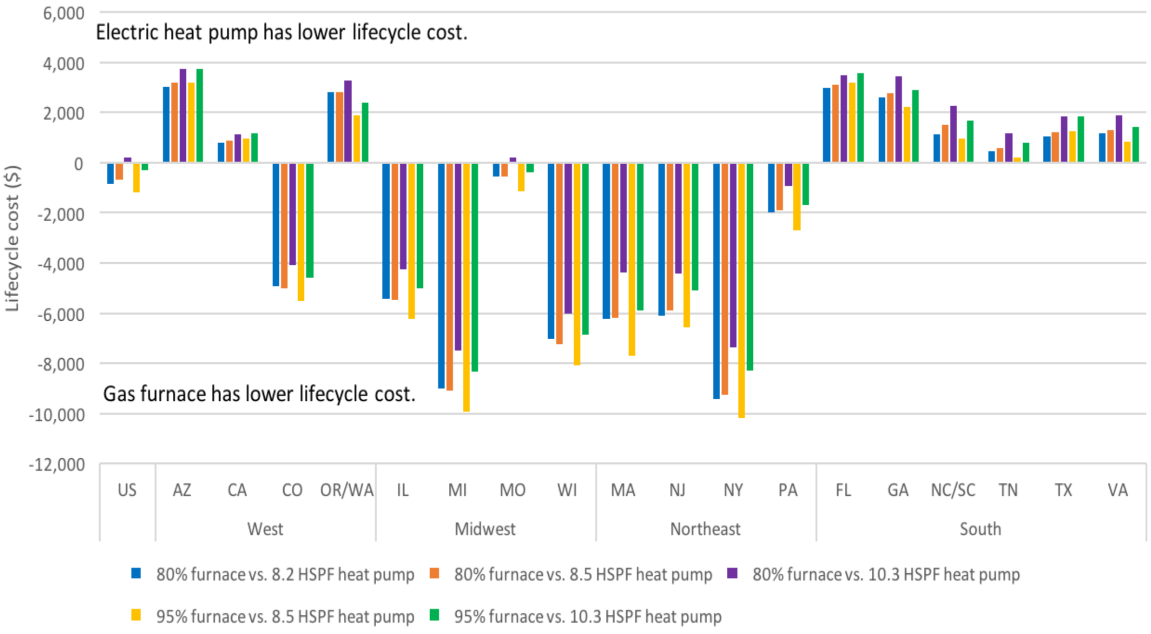

Figure 18. Lifecycle cost comparison of natural gas furnaces and electric heat pumps. *Source:* Nadel 2016.

Conclusions

Energy efficiency has resulted in substantial natural gas savings. Natural gas savings can be attributed to a variety of factors, including savings from technology development, price response, building codes, equipment efficiency standards, and utility-funded energy efficiency programs. Utility-driven savings have been especially big in some leading states, with savings targets, decoupling, and shareholder incentives playing a significant role.

Considerable opportunities remain for additional cost-effective savings, with the achievable savings averaging around 1% of gas sales each year for the next decade or more. Recent studies have found that these savings remain cost effective, even at the relatively low natural gas prices that currently prevail.

Various related issues also merit attention, including the potential for energy savings from CHP systems; appropriate niches for natural gas in transportation; the need for natural gas, electric, and water utilities to work together on efficiency programs; and opportunities for fuel switching.

Natural gas is a large portion of our energy mix, and we have many opportunities to use it more wisely to manage resources, keep energy bills in check, and keep emissions to modest levels. By doing so, we can bolster the US economy and environment.

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Appendix A. Key Calculations, Data, and Assumptions Underlying Estimate of 2030 Technical/Economic Potential

As noted in the main report text, our estimate of savings potential uses the EIA's *Annual Energy Outlook 2017* Reference Case as the foundation for our analysis. Calculations are provided in table A1 and key sources in table A2.

Table A1. Calculation of 2030 energy efficiency potential

Measure	Base use (quads)	% applicable	% saved	Available by 2030	2030 savings (quads)
Residential					
Furnaces	2.38	48%	16%	62%	0.11
Boilers	0.34	54%	13%	52%	0.01
Learning thermostats	2.76	80%	10%	100%	0.22
Showerheads and faucets	0.77	27%	35%	100%	0.07
Clothes washers	0.31	65%	28%	81%	0.05
Water heaters	1.16	95%	19%	100%	0.21
Whole home retrofit	3.02	90%	20%	100%	0.54
Clothes dryers	0.06	83%	20%	81%	0.01
Cooking	0.22	90%	4%	76%	0.01
New construction	0.39	90%	37%	100%	0.13
Behavior	3.30	80%	1%	100%	0.03
Subtotal	4.76		31%		1.39
Commercial					
Heating equipment	1.51	75%	13%	54%	0.08
Water use	0.30	75%	20%	100%	0.05
Water heaters	0.30	55%	15%	100%	0.02
Cooking	0.36	69%	30%	100%	0.07
Smart building measures	2.19	75%	20%	100%	0.33
Whole building retrofit	1.95	90%	25%	100%	0.44
New construction	0.87	90%	40%	100%	0.31
Subtotal	3.27		42%		1.30
Industrial	7.61	100%	33%	100%	2.51
TOTAL	20.34		26%		5.20

Notes to Table A1

- *Base use* is for 2030 and is stated in quadrillion Btu (quads). These projections come from EIA 2017a (*Annual Energy Outlook*). For the industrial sector, energy use includes only use for heat and power, not for use for feedstock, oil/gas fields, and LNG liquefaction.
- Generally, to prevent double counting of savings, we subtract savings from measures higher up the table from the base use.
- Split between residential furnaces and boilers from EIA 2017b.

- Fraction of hot water for showers, faucets, and clothes washers derived from DeOreo et al. 2016.
- *New construction* includes only buildings constructed in 2018 and beyond. Commercial building new floor area from the *Annual Energy Outlook*; for new homes, estimate 1% of the stock added each year.
- *Whole building retrofit* base use excludes the new construction share of the market.
- *% Applicable* is the percentage of base use that a measure applies to.
- Assumptions for *% Applicable* and energy-saving sources are explained in table A2.
- *Available by 2030* is generally 100% except for products that are replaced on failure; for these, we factor in the 13 years of our analysis relative to the product life. (Note: we use a 13-year measure life for water heaters, and hence 100% of the savings are available by 2030.)

Table A2. Key assumptions and sources

Measure	% applicable	% saved
Residential		
Furnaces	DOE 2016a (SNOPR TSD) estimates 52% of furnace sales will be condensing in 2022.	Based on increasing AFUE from 80% to 95%.
Boilers	DOE 2015c (June TSD) estimates 46% of boiler sales will be condensing in 2020.	Current standard is 84%. ENERGY STAR is 90%, but majority of listed products are 95% or above, so our calculations based on 95%.
Learning thermostats	ACEEE est. Not all houses appropriate.	York et al. 2015 estimate 12%, but savings results appear to be a little higher for electricity (which includes cooling savings) than for gas, so we reduce to 10%.
Showerheads & faucets	63% of faucets are 1 gpm or less and 82% of showers are 2.5 gpm or less. We take midpoint of 73%, meaning 27% can still benefit (P. Mayer, Water Demand Management, pers. comm., April 11, 2017).	Based on info at energy.gov/energysaver/reduce-hot-water-use-energy-savings.
Clothes washers	ACEEE est. of % not ENERGY STAR (spec changed in 2015 and data for 2016 not yet available).	For ENERGY STAR Most Efficient from York et al. 2015.
Water heaters	ACEEE est. to exclude niche units and the small number of units that are already condensing.	Based on increasing EF from 62% to 77%.
Whole building retrofit	ACEEE est. A small share of homes will be difficult.	From York et al. 2015.
Clothes dryers	ENERGY STAR (2016) estimates 17% of gas dryers in 2015 met Energy Star levels.	Per ENERGY STAR website: www.energystar.gov/products/appliances/clothes_dryers.
Cooking	deLaski et al. 2016 est. 10% of equipment meet these efficiency levels.	From deLaski et al. 2016 based on DOE NOPR.
New construction	ACEEE est. A modest share of new construction will go well beyond code.	From York et al. 2015.
Behavior	ACEEE est. We exclude low users.	Sussman and Chikumbo 2016.
Commercial		
Heating equipment	deLaski et al. 2016 est. 25% of equipment meet these efficiency levels.	Based on residential boiler calculation and going from 80% to 92% for furnaces.
Water use	ACEEE est. to exclude toughest parts of market.	Rough estimate based on a review of case studies available from Water Sense: www3.epa.gov/watersense/commercial/tools.html#three.
Water heaters	ENERGY STAR (2016) estimates 45% of gas water heaters in 2015 met ENERGY STAR levels (e.g., 94% TE).	Going from 80% TE to 94% TE, per ASAP note re DOE NOPR: appliance-standards.org/product/commercial-water-heaters.
Cooking	ENERGY STAR (2016) estimates 21% of fryers, 20% of griddles, and 53% of steam cookers met ENERGY STAR levels in 2015 (simple average of 31%).	Based on average improvement reported by Food Service Technology Center: www.fishnick.com/equipment/techassessment/1_intro.pdf.
Smart building measures	ACEEE est. We do not include the tougher parts of the market.	From Rogers et al. 2013.
Whole building retrofit	ACEEE est. A small share of buildings will be difficult.	From York et al. 2015.
New construction	ACEEE est. A modest share of new construction will go well beyond code.	From York et al. 2015.
Industrial	Savings are an average for the entire sector.	20% for smart manufacturing (Rogers 2015), 8% SEM (York et al. 2016), plus at least 5% for process measures.