U.S. DEPARTMENT OF ENERGY

ALLIANCE TO SAVE ENERGY

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ACCELERATE ENERGY *Productivity* 2030

A Strategic Roadmap for American Energy Innovation, Economic Growth, and Competitiveness

Accelerate Energy Productivity 2030: A Strategic Roadmap for American Energy Innovation, Economic Growth, and Competitiveness was developed by the U.S. Department of Energy in partnership with the Council on Competitiveness and the Alliance to Save Energy.

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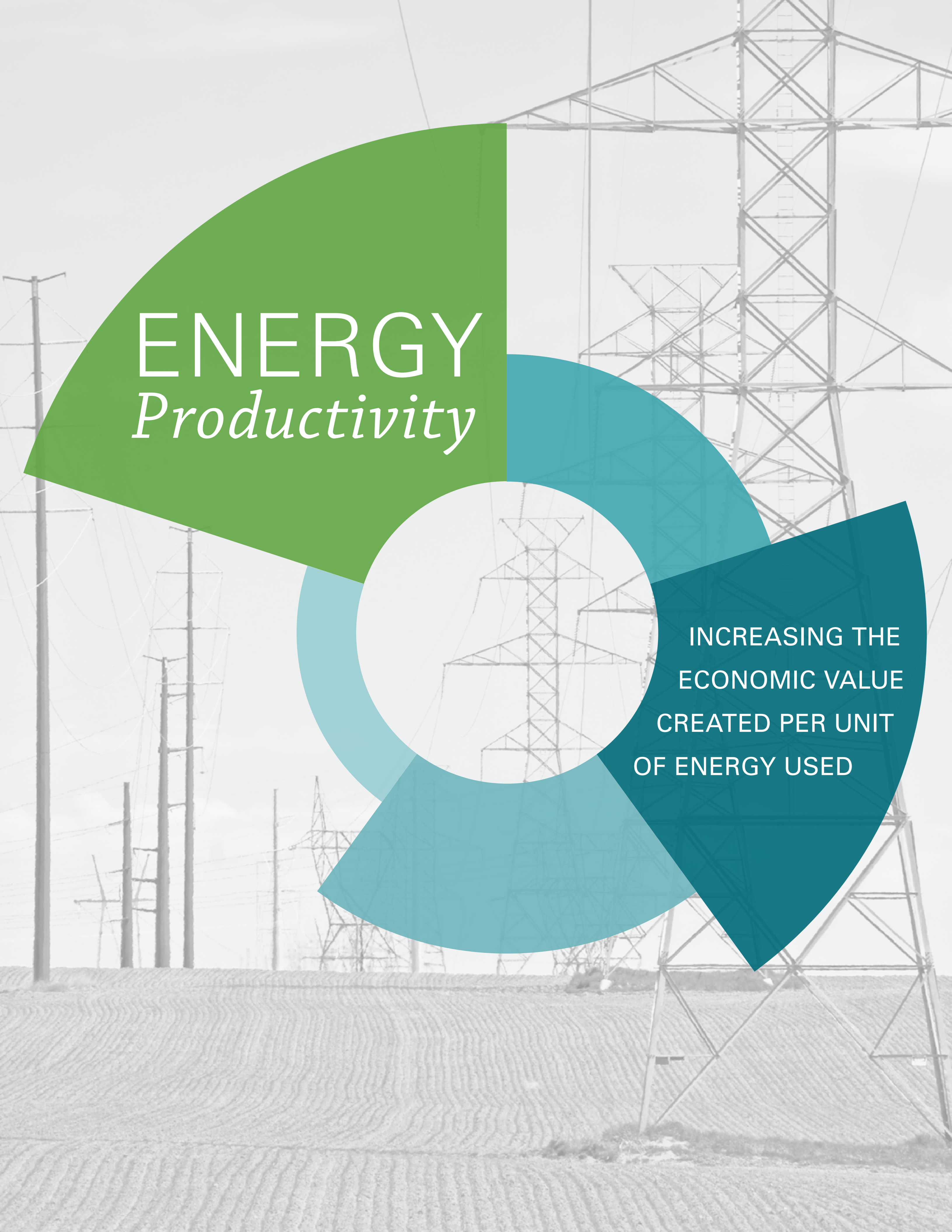
INCREASING THE ECONOMIC VALUE CREATED PER UNIT OF ENERGY USED



EXECUTIVE SUMMARY

In September 2014, responding to the presidential call to action to double energy productivity by 2030, U.S. Secretary of Energy Dr. Ernest Moniz announced the Accelerate Energy Productivity 2030 initiative. The U.S. Department of Energy (DOE) partnered with the Council on Competitiveness and the Alliance to Save Energy (collectively, the Partners) in a series of public dialogues and executive roundtables to raise awareness, galvanize support and develop the strategies necessary to double the United States' energy productivity, defined as the ratio of economic output (gross domestic product (GDP)) to primary energy use.

This publication—*Accelerate Energy Productivity 2030: A Strategic Roadmap for American Energy Innovation, Economic Growth, and Competitiveness* (*Roadmap*)—outlines a set of pathways to achieve this goal, and makes clear the direct, tangible, and long-lasting benefits in doing so: lower energy bills; job creation; economic growth; a more globally-competitive manufacturing and industrial base; and greater prosperity for Americans in the decades to come. This *Roadmap* identifies actions a broad range of stakeholders—including businesses; federal, state, and local governments; universities and community colleges; and individual consumers—can take to achieve the national goal of doubling energy productivity by 2030.

The *Roadmap* is organized around two main findings informed by the work of the Partners over the last 12 months:

1. **There are demonstrated, proven opportunities in every part of our economy to improve energy productivity.** The federal government can support increasing energy productivity in many ways, but cannot achieve the goal on its own. To be successful and achieve this national goal, we need decision-makers across the country also to take action. Attendees of Accelerate Energy Productivity 2030 events discussed a wide range of opportunities for diverse stakeholders to improve their energy productivity and contribute to meeting the national goal. The *Roadmap* highlights these success stories along with other effective approaches to driving increased productivity over the next 15 years.
2. **New analysis shows how energy productivity can contribute to economic growth.** Drawing on discussions from the regional roundtables and dialogues as well as existing studies, DOE analyzed illustrative scenarios under which the United States can meet the president's goal by investing in energy productivity improvements.

Underpinning the *Roadmap* is a newly developed modeling framework that uses historical data to project how changes in investment, energy use, and personal expenditures impact economic activity nationwide. The framework also provides insight into the macroeconomic effects of energy productivity. The model is built on established metrics for the economic and energy outcomes of six significant policy and investment strategies, each of which is based on broad areas of opportunity that stakeholders identified. The model then dynamically analyzes how changes in energy use from these strategies would impact GDP.

SUMMARY: HIGHLIGHTS OF STAKEHOLDER STRATEGIES

The Partners launched a series of dialogues with business, academic, and laboratory leaders; state and local government officials; and researchers to identify the most promising pathways to meet the national goal of doubling energy productivity by 2030. These three regional dialogues and roundtable discussions have informed the sample strategies explored in the *Roadmap*. Example strategies described in the *Roadmap* are presented by entity: federal, state, and local governments; commercial and industrial businesses; electric, gas, and water utilities; higher education institutions; and households. The strategies presented here are not meant to be comprehensive. Rather, the *Roadmap* focuses on scalable actions that have the potential to reduce energy consumption and support economic growth. These energy productivity strategies often involve multiple economic sectors and levels of government. To present a cohesive analysis of the potential impacts of the strategies, this analysis developed six productivity "wedges" as representations of aggregated individual strategies. These wedges are summarized in Section 3.

Taken together, these strategies offer a feasible path to the doubling of national energy productivity by 2030. The strategies also indicate that participating entities—including both individuals and organizations—can enjoy a potential share of the benefits of achieving this goal.

Government

- *Federal Government:* Invest in long-term energy productivity through research, development, and demonstration in transportation, buildings, and manufacturing technologies; secure energy productivity through setting and updating vehicle and product codes and standards, and providing energy performance information to consumers; support policy action by state and local governments and the private sector through the provision of tools and other resources to reap the benefits of energy efficiency; set the financial foundation for energy productivity through tax policies; help train a workforce geared for energy productivity; and lead by example in adopting new technologies and strategies in its own operations.
- *State Government:* Pursue policies to encourage greater energy efficiency; promote new and innovative financing for investments that support energy productivity; support and incentivize increased deployment of combined heat and power

(CHP); implement smart regional transportation solutions; and adopt and enforce increasingly efficient building codes.

- *State Regulators:* Adopt rates and implement related policies affecting utility sector efficiency programs that more effectively align efficiency efforts with utility business models; and support energy productivity investments in buildings and infrastructure.
- *Local Government:* Facilitate distributed generation; establish best practices regarding building energy information; support the development of advanced manufacturing ecosystems; and reduce personal vehicle miles traveled[1] through the built environment-transportation nexus.
- *National Laboratories:* Serve as incubators for new energy productivity technologies—and where appropriate, enable new energy-efficient technologies to move rapidly from the lab to the marketplace.

Businesses

- *Commercial Businesses:* Reduce energy consumption in their own buildings and facilities through energy efficiency; reinvest the resulting avoided energy costs into growing their businesses; adopt new financing models that promote energy productivity investments; encourage their suppliers and vendors to take measures to improve energy productivity; and assist in training a workforce geared for energy productivity.
- *Industrial Businesses:* In addition to taking similar steps to those taken by commercial entities, leverage public-private partnerships; adopt energy management systems; transition to advanced manufacturing technologies; and explore new, innovative products that enable energy productivity for customers and suppliers.

Utilities

- *Electric Utilities:* Modernize the grid infrastructure through smart grid investments and improving the efficiency and interoperability of generation, transmission, storage, and distribution; adopt new utility business models to empower the improvement of energy productivity; design rates and support related policies for utility energy efficiency programs that more effectively align energy efficiency with utility business models; and support energy productivity investments in buildings.
- *Water Utilities:* Adopt more energy-efficient and energy-extracting technologies at water and wastewater treatment facilities and more water-efficient technologies in distribution and end use water systems (e.g., wastewater treatment plants can implement more efficient pumps and deploy onsite waste to energy conversion, such as digesters and combined heat and power; end use hot water conservation measures also have a direct impact on energy consumption).

Higher Education Institutions, and Individuals and Households

- *Higher Education Institutions:* Create new curricula and expand workforce training opportunities across multiple disciplines (e.g., building trades, engineering, governmental policy, economics, and law) for careers in the clean

1 Vehicle miles traveled is a measure of distance traveled by vehicles over a given period, typically one year.

energy, energy efficiency, and advanced manufacturing fields; and act as demonstration and commercialization "accelerators," enabling new energy-productive technologies to move rapidly from the lab to the marketplace. In addition, higher education institutions can invest in making their facilities and fleets more efficient.

- *Individuals and Households:* Support the markets associated with energy-efficient products in the home and for transportation and use available resources to make informed choices.

MODELING ENERGY PRODUCTIVITY IMPROVEMENTS

To model the effect of the aforementioned strategies for energy productivity on the U.S. economy, the *Roadmap* describes six illustrative productivity "wedges" that collectively represent the strategies. Underlying each wedge are assumptions based on existing published studies of the effect of productivity investments on energy use in a particular sector of the economy. As a result, the wedges are representative of the types of first order effects one could anticipate from the strategies and actions identified in the *Roadmap*.

Using the wedges as a model input, the *Roadmap* employed a vector error correction model (VECM) to estimate the effect of the wedges on U.S. GDP. Although there are many different types of econometric models, VECMs have two advantages. First, they robustly capture interactions and feedback between sectors of the economy using historical relationships. And second, they dynamically estimate future effects of changes to the economy using those historical relationships. In other words, VECMs do not assume GDP remains fixed like many static models but allow, for example, changes in energy efficiency investment to produce GDP feedback effects through changes in energy prices and the amount of energy consumed, among other factors.

After running the model, the *Roadmap* is able to rank the six wedges according to their net effect on GDP. The wedges analyzed are not the only six options available for improving energy productivity, but are intended to be illustrative of the types of energy and economic changes that are expected from following *Roadmap* strategies and actions. The six wedges are presented in descending order of their estimated impact to U.S. energy productivity[2]:

- *Transportation:* Increasing the energy productivity of moving goods and people relies on developing and deploying new technologies that increase vehicle efficiency, create more options for mass transit, and better integrate transportation needs with the built environment to reduce the demand for motorized transport.
- *Technologies for Buildings Energy Productivity:* Improving the energy productivity of buildings requires both the widespread use of currently available energy-efficient technologies and practices, and the development of next generation technologies.
- *Smart Energy Systems:* Energy systems, particularly electricity generation systems and the electricity grid, are sources

2 Economic and energy effects are not estimated for wedge sub-elements. As a result, it is not possible to determine the relative impacts to energy productivity of wedge sub-elements.

and enablers of improvements to U.S. energy productivity. Broad and deep transformations are required to enable transitions to distributed energy resources, real-time energy pricing, smart appliances, and increased energy efficiency.

- *Financing for Buildings Energy Productivity:* Significant changes to financing mechanisms and market recognition of the value of energy productivity are required to ensure energy productivity-enabling technology is used by businesses and households. This includes addressing real or perceived risk to the use and deployment of these technologies, which can immediately and adversely impact the cost of financing.
- *Smart Manufacturing:* Sensors and other information and communications technology (ICT) will allow industries better control over their processes and will improve the energy management of their buildings.
- *Water Infrastructure:* Reducing energy consumption at water and waste water treatment plants and in water conveyance and distribution systems involves three actions: improving energy efficiency and demand response, implementing emerging technologies and processes, and deploying energy recovery and generation technologies.[3]

DOUBLING ENERGY PRODUCTIVITY BY 2030 IS ACHIEVABLE

The analysis demonstrates that through immediate and sustained actions, doubling energy productivity by 2030 is possible. The model estimates the energy productivity wedges increase energy productivity in 2030 to $287/million British thermal units (Btu) (MMBtu)— more than double the 2010 baseline of $134/MMBtu. The change in energy productivity is the result of increasing GDP ($2005) to $22.5 trillion and reducing primary energy use to 78 quadrillion (quads) Btu by 2030. In comparison, the Energy Information Administration's (EIA) *Annual Energy Outlook* (AEO) 2015 projections are $21.7 trillion and 103 quads Btu in 2030. Thus, in 2030, the *Roadmap* scenario achieves 3.6 percent higher GDP and 24 percent lower primary energy use than AEO 2015 projections. The model does account for energy used to produce the additional goods and services purchased by households. This results in aggregate energy savings values, including this additional energy from more goods and services, are approximately 14 percent smaller than the sum of each individual productivity wedge, as indicated by the dashed line in Figure 1.

3 Pabi, S., A. Amarnath, R. Goldstein, and L. Reekie, Electricity Use and Management in the Municipal Water Supply and Wastewater Utilities (Palo Alto, CA: Electric Power Research Institute, 2013), accessed July 2015, http://www.waterrf.org/PublicReportLibrary/4454.pdf.

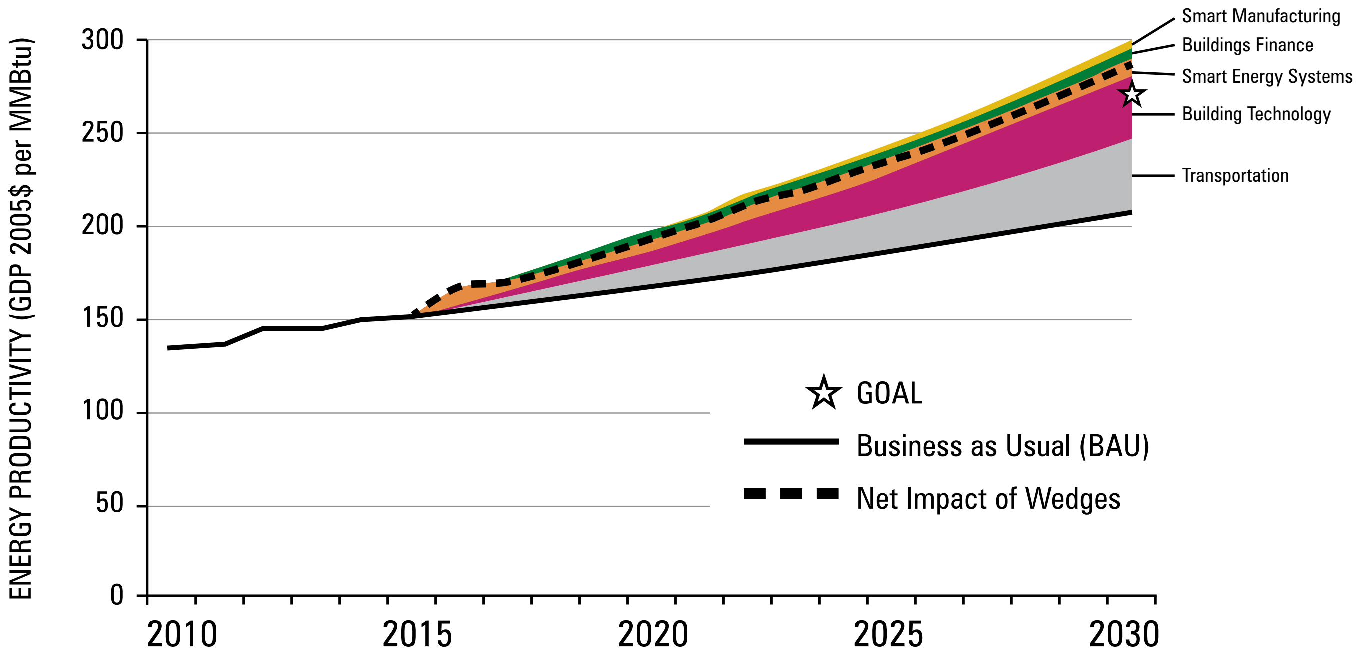


Figure 1. Estimated Energy Productivity Benefits to 2030

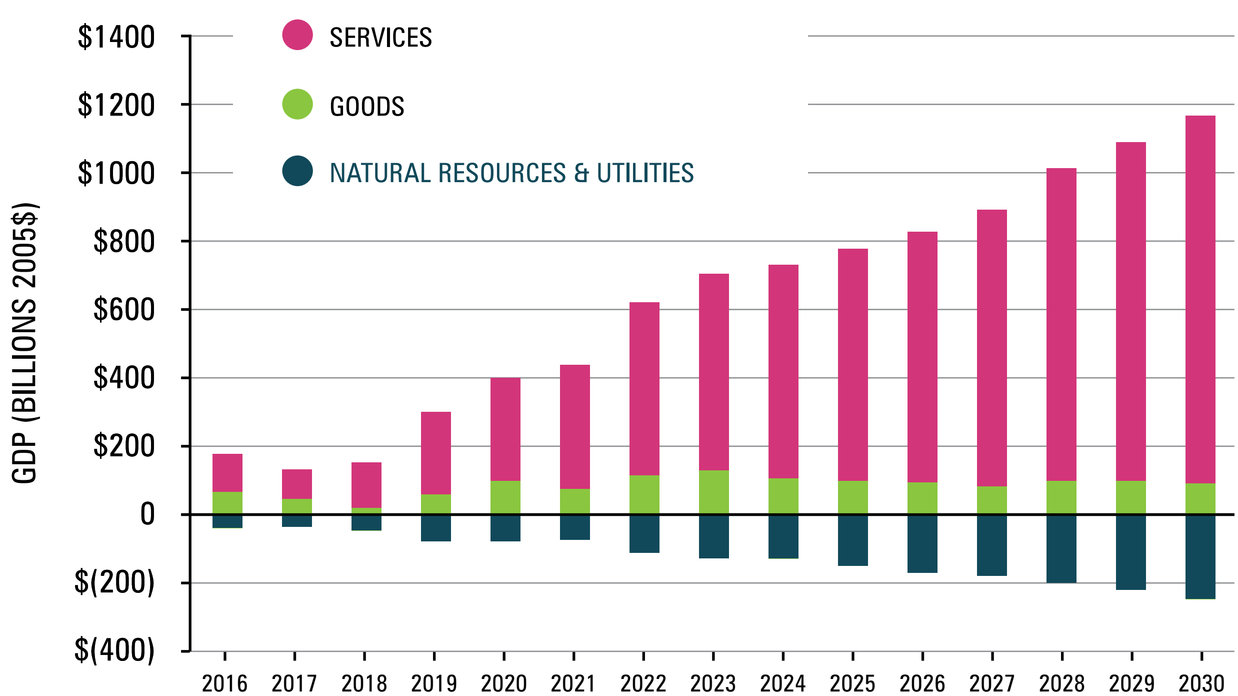


Figure 2. Estimated Changes to GDP by Sector

According to the model underpinning the *Roadmap*, the six energy productivity wedges will contribute in aggregate to a net increase of $922 billion in U.S. GDP by 2030. This is primarily supported by an increase of $753 billion in household expenditures and by a $169 billion increase in investment in products and services that increase energy efficiency. For households, there is a double benefit: they are able to increase their purchases of other goods and services in part by making energy efficiency investments that reduce their energy bills. Figure 2 shows the estimated changes to GDP by sector.

Producers of goods and services are also shown to benefit from increased economic activity spurred by energy productivity investments. The service industry shows the most significant growth, with a nearly $1.08 trillion increase over baseline economic activity by 2030. By 2030, goods-providing industries (e.g., manufacturing, agriculture, and construction) increase by approximately $51 billion over the model baseline. Declines in economic activity in the natural resources and utilities are due to decreases in energy expenditures and demand for production from utilities and their supply chain. No specific assumptions are made concerning export markets for natural resources.

CONCLUSION

As is clear from the Accelerate Energy Productivity 2030 regional roundtables and dialogues, as well as the modeling analyses, a wide range of available activities will yield significant productivity benefits. Implementing these activities will require changes in behavior, investment, and technology deployment in both the public and private sectors. Collectively, they can improve U.S. economic output, reduce U.S. energy consumption, and reduce the energy impact on the environment. Government and the private sector are already deploying many of these changes. While the task of doubling energy productivity is a significant challenge, the fact that many activities are already underway suggests that the nation can – and already is – beginning to meet this challenge. The *Roadmap* provides a foundation for scaling these efforts nationwide while allowing for flexible and tailored solutions.

Increasing energy productivity is doing more with less, generating greater economic well-being for the amount of energy used, and improving living standards and quality of life.

INTRODUCTION TO THE ROADMAP

In his 2013 State of the Union address, President Obama announced the bold goal of doubling energy productivity with the statement, "I'm also issuing a new goal for America: Let's cut in half the energy wasted by our homes and businesses over the next 20 years."[4] The goal of doubling energy productivity complements other administration goals, such as deploying 40 gigawatts (GW) of new combined heat and power (CHP) by 2020.[5]

Secretary Moniz echoed the president's remarks, stating, "Taking action today to increase our energy productivity, by boosting the competitiveness of American manufacturers and building clean energy technologies here in the U.S., will help grow our economy for generations to come."[6] In November 2014, Secretary Moniz on behalf of DOE, the Council on Competitiveness, and the Alliance to Save Energy (the Partners) created the Accelerate Energy Productivity 2030 initiative. And, the Partners jointly launched a series of three dialogues (Appendixes 3–5) with business, academic, and laboratory leaders; state and local government officials; and researchers to identify the most promising pathways to meet the national goal of doubling energy productivity by 2030. These regional dialogues—in Raleigh, Seattle, and St. Paul—and accompanying roundtable discussions informed the sample strategies explored in this document: *Accelerate Energy Productivity 2030: A Strategic Roadmap for American Energy Innovation, Economic Growth, and Competitiveness.*

The challenges facing the adoption of energy-efficient technologies and behavior are well-documented.[7] The recent

4 The White House Office of the Press Secretary, "Remarks by the President in the State of the Union Address," news release, February 12, 2013, https://www.whitehouse.gov/the-press-office/2013/02/12/remarks-president-state-union-address.

5 The White House Office of the Press Secretary, "Executive Order -- Accelerating Investment in Industrial Energy Efficiency", news release, August 30, 2012, https://www.whitehouse.gov/the-press-office/2012/08/30/executive-order-accelerating-investment-industrial-energy-efficiency.

6 U.S. DOE. 2015. Accelerate Energy Productivity 2030 Fact Sheet. http://energy.gov/epsa/downloads/accelerate-energy-productivity-2030-fact-sheet.

7 William H. Golove and Joseph H. Eto, Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency, LBL-38059 (Berkeley, CA: Lawrence Berkeley National Laboratory, 1996), accessed July 2015, http://eetd.lbl.gov/sites/all/files/lbnl-38059.pdf; Steve Sorrell, Eoin O'Malley, Joachim Schleich, and Sue Scott, The Economics of Energy Efficiency: Barriers to Cost-Effective Investment (Cheltenham, UK: Edward Elgar Publishing, 2004); Richard B. Howarth and Bo Andersson, "Market Barriers to Energy Efficiency," Energy Economics 15:4 (1993): 262–272.

recession highlighted structural impediments to robust continual economic growth. The loss of economic potential[8] in 2015 due to effects of the recession is estimated to be between 5.3 percent and 7.7 percent.[9] With a focus on producing more economic output with less energy, the national goal to double energy productivity encompasses strategies focusing on reducing energy consumption as well as growing the economy.

Since 2014, the federal government has implemented several significant actions that will accelerate U.S. energy productivity:

- DOE adopted new appliance efficiency standards, in addition to those issued since 2008, that will help households save over $26 billion on their utility bills by 2030.[10]
- DOE and the U.S. Department of Housing and Urban Development launched an initiative to increase energy literacy to support science, technology, engineering, and mathematics (STEM) fields.
- The Green Preservation Plus loan program was expanded to improve further the efficient use of energy and water in multifamily properties.[11]
- As part of President Obama's Climate Action Plan, the federal government created three "Better Buildings Accelerators" (BBA) in 2013, bringing the total number of accelerators to seven.[12]
- Federal buildings were given an additional $2 billion goal for energy efficiency investments, which will create tens of thousands of new jobs at no net cost to taxpayers through reduced energy expenditures.

The strategies presented in this *Roadmap* build on these existing efforts and provide stakeholders with the information needed to undertake similar efforts themselves. The *Roadmap* does not provide an exhaustive list of strategies and actions that could double energy productivity. Rather, the strategies presented here represent a survey of known, demonstrated, and replicable options for the United States to reach the goal of doubling energy productivity.[13]

8 Economic potential refers to the normal level of GDP that could be expected for an economy given its available resources and technology. See Pierre-Olivier Beffy, Patrice Ollivaud, Pete Richardson, and Franck Sédillot, New OECD Methods for Supply-side and Medium-term Assessments: A Capital Services Approach (Paris: Organisation for Economic Co-operation and Development, 2006), accessed July 2015, http://dx.doi.org/10.1787/628752675863.

9 Lawrence M. Ball, Long-Term Damage from the Great Recession in OECD Countries, NBER Working Paper No. 20185 (Cambridge, MA: National Bureau of Economic Research, 2014), accessed July 2015, http://www.nber.org/papers/w20185.

10 The White House Office of the Press Secretary, "Fact Sheet: President Obama Announces Commitments and Executive Actions to Advance Solar Deployment and Energy Efficiency," news release, May 9, 2014, https://www.whitehouse.gov/the-press-office/2014/05/09/fact-sheet-president-obama-announces-commitments-and-executive-actions-a.

11 Fannie Mae, "HUD and Fannie Mae Announce Expansion of Green Preservation Plus," news release, May 8, 2014, http://fanniemae.com/portal/about-us/media/corporate-news/2014/6117.html.

12 "Accelerating Investment in Energy Efficiency," U.S. Department of Energy Better Buildings, accessed July 2015, http://www1.eere.energy.gov/buildings/betterbuildings/accelerators/.

13 Note that reference to any non-Federal entity in this document does not constitute an endorsement on the part of DOE or the U.S. government.

The Clean Power Plan and Energy Productivity

On August 3, 2015, President Obama and EPA Administrator Gina McCarthy announced the Clean Power Plan (CPP), new regulations that will reduce carbon emissions from new and existing power plants. States can draw on a wide range of options to meet the emissions standards outlined in the plan, designed to allow states to choose plans that work for their unique energy mix, resources and economy.

Because each of the Accelerate Energy Productivity 2030 regional dialogues occurred before the Clean Power Plan was finalized, discussions at these dialogues were not intended to address the CPP. However, many of the strategies in this Roadmap can increase energy productivity while also assisting with CPP compliance, including shifting to renewable electricity generation as well as efficiency improvements at power plants, transmission and distribution infrastructure, and ramping up demand-side energy efficiency.

For more information on the CPP, please visit http://www2.epa.gov/cleanpowerplan. For information on DOE resources that could be helpful for state plans, please visit www.doe.gov/ta.

1.1 Energy Productivity

ENERGY EFFICIENCY VS. ENERGY PRODUCTIVITY

ENERGY EFFICIENCY *provides the same level of goods and services using less energy.*

ENERGY PRODUCTIVITY *increases the economic value created per unit of energy used.*

Energy is a foundation for economic activity and a requisite for every product we buy and every service we use. Increasing energy productivity is doing more with less, generating greater economic well-being for the amount of energy used, and, critically, improving living standards and quality of life. National efforts to boost energy productivity date back at least 35 years. In 1981, the United States Congress Joint Economic Committee worked to develop a national energy productivity index,[14] and the concept gained momentum more recently through announcements like President Obama's goal of doubling energy productivity by 2030.

Energy productivity (the inverse of energy intensity) is defined in the *Roadmap* as the ratio of annual GDP to annual total primary energy use. The energy productivity of an economy, like its energy intensity, is a highly aggregated measure of energy use and economic output. As a result, the energy productivity metric reflects many underlying factors, including structural changes (i.e., changes to the relative contribution of different economic sectors) and changes in energy efficiency (i.e., changes to the amount of energy used to provide a good or service). Unlike analysis that aims to distinguish the impacts of energy efficiency to national energy use,[15] the energy productivity analysis completed here implicitly includes structural, efficiency-

14 A. Penze and D. Bakke, A National Index for Energy Productivity (Washington, D.C.: Joint Economic Committee (U.S. Congress), 1981), accessed July 2015, http://www.osti.gov/scitech/biblio/6531717.

15 Energy Intensity Indicators," U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, last modified March 3, 2015, http://www1.eere.energy.gov/analysis/eii_index.html.

International Interest in Energy Productivity

The United States is not alone in its interest in increasing energy productivity. A number of governments and international actors are embracing this framework to set or support the achievement of national and regional goals. Additional information on international interest in energy productivity can be found in Appendix 1.

related, and activity-related factors, and it does not separately identify the GDP or energy effects of each factor.

Because energy productivity is defined as a ratio, increasing energy productivity can be achieved by either growing GDP at a faster rate than energy use or reducing the growth rate of energy use to a rate of growth less than GDP growth. However, energy use and GDP are linked and tend to move in the same direction (see Figure 3), raising concerns that any reduction in the rate of growth of energy use may contribute to lower GDP growth. Analysis conducted for the *Roadmap*, which is discussed in Section 3, examines the interaction between energy use and GDP and estimates the net impacts to GDP, energy use, and energy productivity.

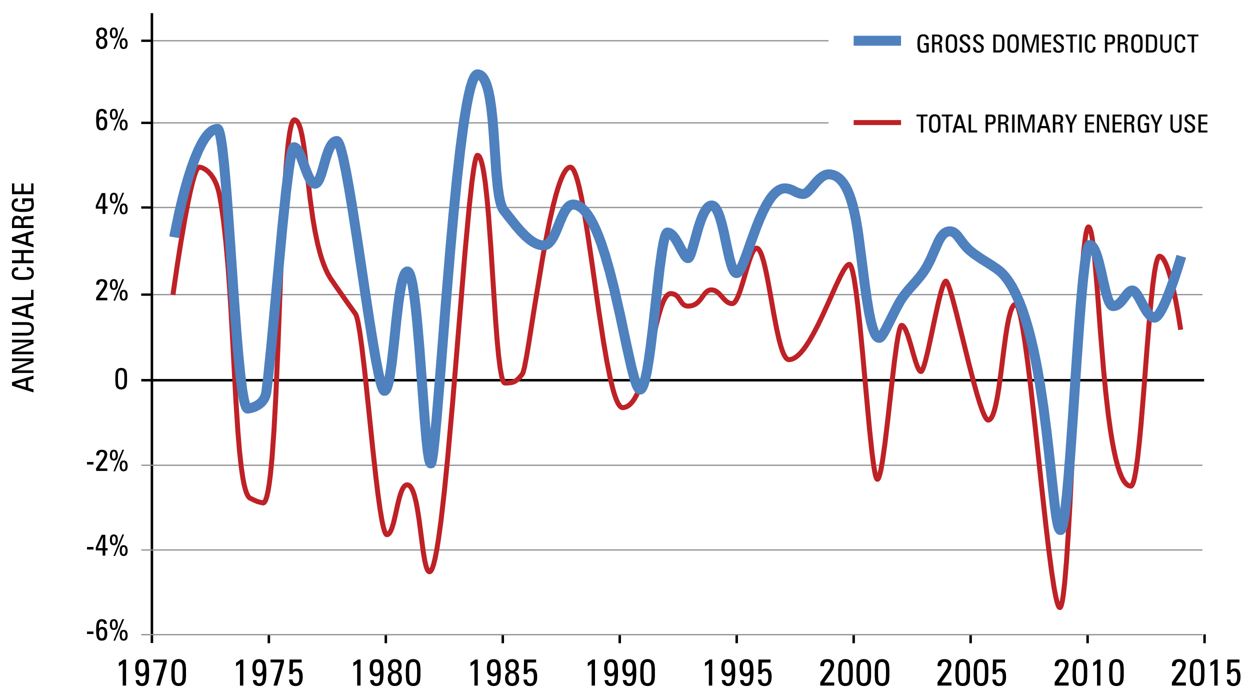


Figure 3. U.S. Total Primary Energy and Real GDP (1971–2014)[16]

16 GDP in chain-weighted 2005 dollars from the Bureau of Economic Analysis; total primary energy from the Energy Information Administration, adjusted for International Energy Agency accounting of renewable electricity.

1.2 Overview of the 2030 Productivity Goal

1.2.1 SYNOPSIS OF CURRENT ENERGY USE AND ECONOMIC ACTIVITY

Figure 4 summarizes the trends in U.S. GDP and primary energy use since 1970. As the figure depicts, primary energy use for the period peaked in 2007, and it remains largely flat since 2000. Conversely, GDP has grown for most of the period. In 2010, the U.S. economy produced approximately $136 (chained 2005 dollars[17]) in GDP for each MMBtu used.[18]

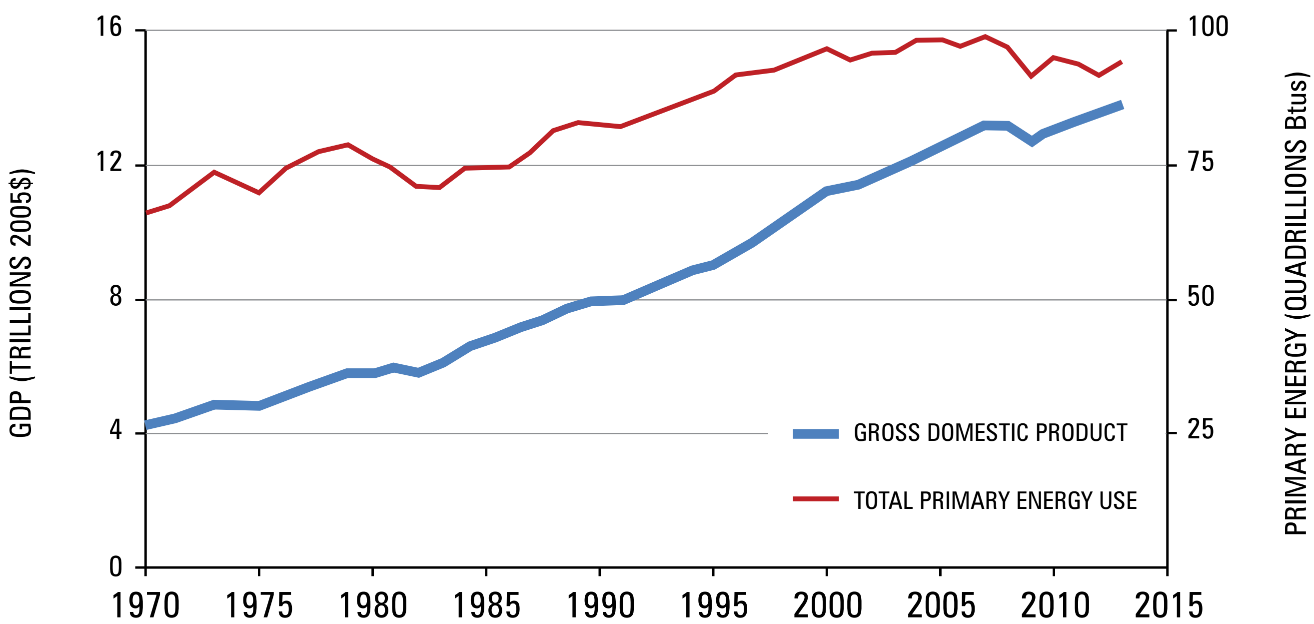


Figure 4. U.S. GDP and Total Primary Energy Use (1970–2014)

17 The U.S. Bureau of Economic Analysis uses chain-weighted indexes to adjust nominal estimates of GDP to account for inflation.

18 National primary energy accounting is performed on a "production" rather than a "consumption" basis. This means that national energy data does not include the energy used to create imported materials and products (i.e., "embodied" energy), and they do not subtract energy used to produce exported materials and products.

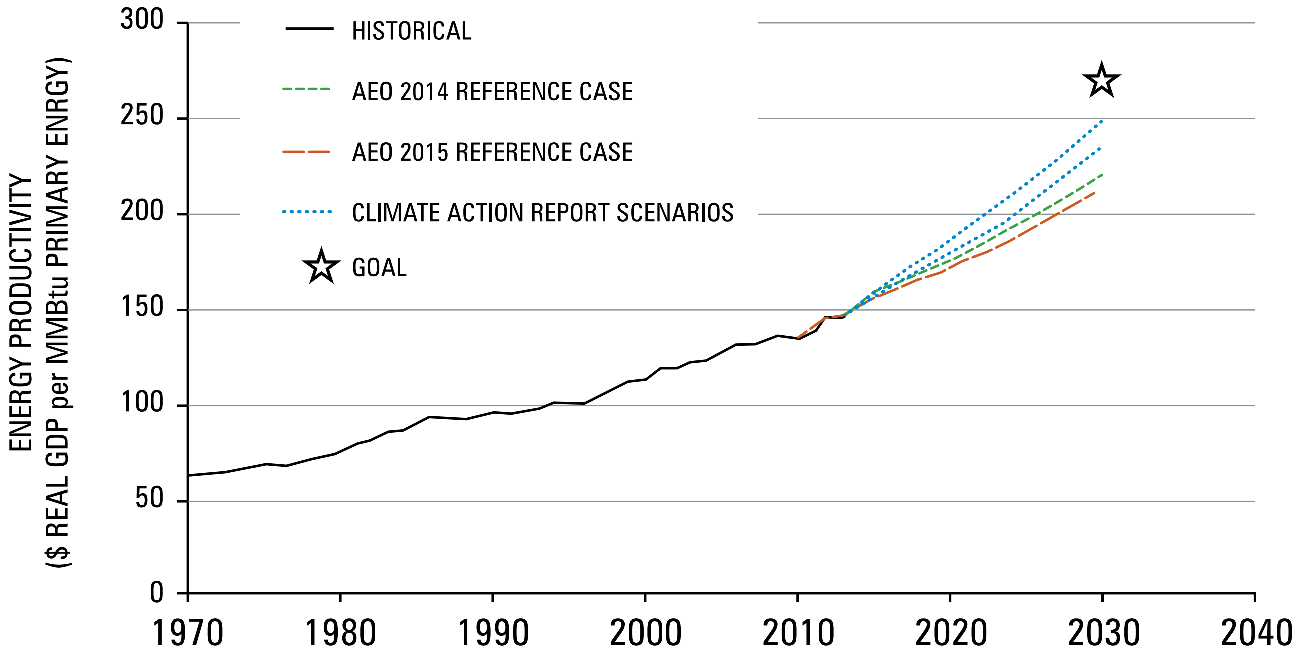


Figure 5. Historical and Projected Energy Productivity (1970–2030)

Figure 5 summarizes the historical performance and projected trends in U.S. energy productivity. Energy productivity has increased since 2010, reaching $149 per MMBtu in 2014. The business-as-usual (BAU) pathway is represented by the U.S. Energy Information Administration's (EIA's) Annual Energy Outlook (AEO) 2014 Reference Case, and it achieves 57 percent of the goal. A combination of nearly flat primary energy demand growth (0.24 percent average annual growth rate from 2010 to 2030) and moderate economic growth forecast (2.43 percent average annual growth rate from 2010 to 2030) drive BAU improvements.

The Side Cases of AEO 2014 offer scenarios for how policy and technology may affect the U.S. energy productivity trajectory. Yet, even the most aggressive energy efficiency Side Case in AEO 2014, Best Available Technology, represents only a 6 percent improvement in energy productivity by 2030 over the AEO 2014 Reference Case BAU, achieving 70 percent of the goal by 2030.[19]

19 The EIA did not conduct any energy efficiency Side Cases for the 2015 AEO.

Actions identified in the 2014 *Climate Action Report*[20] could lead to as much as a 62 percent increase in energy productivity over the AEO 2014 Reference Case BAU. However, achieving the remaining portion of the goal will require *significant* additional actions in transforming how the U.S. economy provides and uses energy. The most effective strategies for meeting the productivity goal will involve both reducing energy use and increasing economic growth; however, there is another significant opportunity to improve energy use intensity by modernizing the manufacturing sector to use innovative, effective, and more efficient manufacturing processes. Achieving the goal within the current national economic-energy structure will require significant action on the part of government, private businesses, and individual citizens.

1.2.2 IDENTIFIED ENERGY PRODUCTIVITY POTENTIAL

1.2.2.1 Synopsis of Existing Studies and Strategies

The *Roadmap* follows on a report[21] commissioned by the Alliance to Save Energy that identifies specific strategies for doubling U.S. energy productivity by 2030. The 2013 report's supporting analysis of the impacts of doubling energy productivity estimates that an additional $166 billion annual investment in energy efficiency in the buildings, industry, and transportation sectors could reduce energy use in 2030 by 18 percent relative to 2011 levels and save $343 billion in annual energy costs.[22] Together with savings of $151 billion from lower energy prices that could result from decreased demand, the annual savings by 2030 would equal approximately $327 billion, which is equivalent to 2 percent of nominal GDP in 2030. The analysis also highlighted associated benefits of increased net employment, reduced greenhouse gas emissions, and improved energy security. The net economic effects of these savings and investments (i.e., changes to GDP) were not estimated in the 2013 report.

In 2012 the Alliance to Save Energy's Commission on National Energy Efficiency Policy issued a set of 54 diverse policy recommendations in 2012 that, taken together with the elements of this *Roadmap*, could achieve the goal of doubling U.S. energy productivity. The report[23] highlights the roles of utilities, residential and commercial buildings, industries, and the transport sector in achieving cost-effective energy efficiency improvements. The report also provides

20 The Climate Action Report identifies potential greenhouse gas emissions reduction scenarios from private sector uptake of federal government greenhouse gas emissions mitigation measures. See U.S. Department of State, United States Climate Action Report 2014 (Washington, D.C.: U.S. Department of State, 2014), accessed July 2015, http://www.state.gov/documents/organization/219038.pdf.

21 Rhodium Group, American Energy Productivity: The Economic, Environmental and Security Benefits of Unlocking Energy Efficiency (New York, 2013), accessed July 2015, http://www.ase.org/sites/ase.org/files/rhg_americanenergyproductivity_0.pdf.

22 Rhodium Group, American Energy Productivity: The Economic, Environmental and Security Benefits of Unlocking Energy Efficiency.

23 Alliance to Save Energy, Doubling U.S. Energy Productivity by 2030, accessed July 2015, http://www.ase.org/sites/ase.org/files/full_commission_report.pdf.

recommendations for accelerating energy innovation through research, development, demonstration, and deployment. The Bipartisan Policy Center also has issued a report that includes recommendations for improving the nation's energy productivity.[24] In addition to proposing policies like those contained in the Alliance's report, the Bipartisan Policy Center also recommends expanding the portfolio of energy resources; and modifying the federal government's role in energy markets, both of which may support achieving the energy productivity goal.[25]

The Council on Competitiveness and DOE's Clean Energy Manufacturing Initiative also focuses the nation's most senior private and public sector leadership on opportunities around energy productivity. The American Energy and Manufacturing Competitiveness Partnership—launched in 2012 and encompassing a series of nine dialogues and three summits—catalyzed a movement and set of recommendations to drive energy productivity through new-to-the-world public-private partnerships.[26] The partnership has two clear goals: to increase U.S. competitiveness in the production of clean energy products and to increase U.S. manufacturing competitiveness across the board by increasing energy productivity.

1.3 A Sample of Existing Efforts within and across the Federal Government

1.3.1 RESEARCH AND DEVELOPMENT OF NEW TECHNOLOGIES FOR INCREASING ENERGY PRODUCTIVITY

The federal government maintains a long-standing commitment to performing research and development in energy technology areas where private investments may not yet be justified. Research and development (R&D) funded in these areas is taking place at DOE, DOE national laboratories, the National Science Foundation, and Department of Defense (DOD). Examples of DOE program successes are included throughout the section on strategies for accelerating energy productivity (Section 2).

24 Bipartisan Policy Center, America's Energy Resurgence: Sustaining Success, Confronting Challenges (Washington, D.C.: Bipartisan Policy Center, 2013), accessed July 2015, http://bipartisanpolicy.org/library/americas-energy-resurgence-sustaining-success-confronting-challenges/.

25 Bipartisan Policy Center, America's Energy Resurgence: Sustaining Success, Confronting Challenges.

26 "American Energy & Manufacturing Competitiveness (AEMC) Partnership," Council on Competitiveness, accessed July 2015, http://www.compete.org/initiatives/compete-energy-a-manufacturing/22-aemc.

1.3.2 PROGRAMS TO DEPLOY INNOVATIVE TECHNOLOGIES

Once a new technology or practice is successfully demonstrated, financial and informational barriers can slow adoption. The federal government and its partners continue to address these barriers by helping energy consumers across all economic sectors manage their energy use and costs based on accessing the information needed to take action. Examples include the DOE Federal Energy Management Program (FEMP)'s energy savings performance contracts (ESPCs), DOD test beds, the General Services Administration's Green Proving Ground program, DOE's Weatherization and Intergovernmental Programs Office, the DOE and Environmental Protection Agency (EPA)'s State and Local Energy Efficiency in Action Network (SEE Action), and the Better Buildings Challenge initiative.

1.3.3 SETTING THE BAR FOR ENERGY PERFORMANCE

Through both market-based voluntary programs and regulatory standards, the federal government identifies commercial products that can be manufactured to limit the amount of energy needed to operate them, providing significant cost savings to the end user as well as significant public benefits. Examples include appliance standards, the EPA-led ENERGY STAR®, and vehicle fuel economy standards. For instance, DOE developed energy conservation standards for appliances and equipment, which saved consumers $60 billion on their energy bills in 2014.[27] This reduction of absolute energy use contributes directly to increasing energy productivity.

27 U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, Saving Energy and Money with Appliance and Equipment Standards in the United States, DOE/EE-1086 (Washington, D.C.: U.S. Department of Energy, 2015), accessed July 2015, http://energy.gov/sites/prod/files/2015/07/f24/Appliance%20and%20Equipment%20Standards%20Fact%20Sheet%207-21-15.pdf.

The ten energy efficiency standards DOE finalized in 2014 alone will save U.S. families and businesses an estimated $67 billion in electricity bills through 2030.

STRATEGIES AND ACTORS FOR ENERGY PRODUCTIVITY

Achieving the goal of doubling energy productivity by 2030 will require action across the economy, in both the private and public sectors. This section identifies strategies for achieving the goal within each major sector. These strategies were gathered from roundtable discussions, regional dialogues, and endorsers of the goal that include a wide array of energy efficiency, energy productivity, smart grid, clean energy, advanced manufacturing, clean transportation, and other organizations committed to promoting energy-efficient economic growth. While not an exhaustive list, strategies provided in the *Roadmap* form a foundation to accelerate U.S. energy productivity. They also illustrate the broad range of actions available to citizens and a wide range of stakeholder groups that can share the benefits of achieving the productivity goal.

The energy productivity strategies presented in the *Roadmap* often involve multiple economic sectors and levels of government. To present a cohesive analysis of the potential impacts of the strategies, six productivity "wedges" were developed as representations of aggregate individual strategies. Table 1 provides a brief description of each wedge; Section 3 provides details about how the wedges were used in the energy productivity analysis. The six energy productivity wedges are color-coded throughout the *Roadmap*. The beginning of each strategy section identifies the relevant energy productivity wedges to highlight the connections between the strategies and the energy productivity analysis.

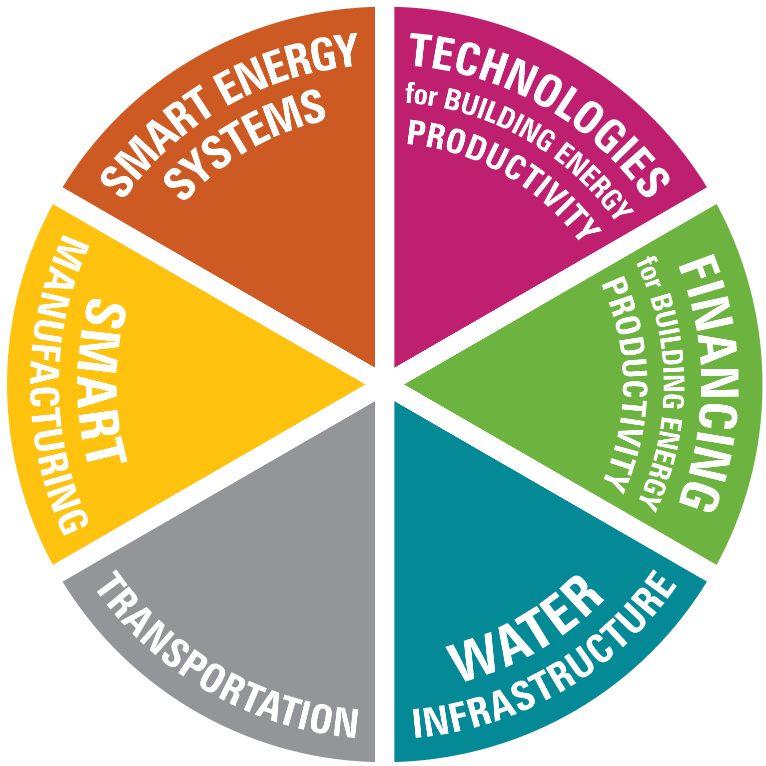


Table 1. Analysis Sources and Inputs: Summary Description of Energy Productivity Wedges

Energy Productivity Wedge	Description
Smart Energy Systems	Energy systems, particularly electricity generation systems and the electricity grid, are sources and enablers of improvements to U.S. energy productivity. Broad and deep transformations are required to enable transitions to distributed energy resources, real-time energy pricing, smart appliances, and increased energy efficiency.
Technologies for Buildings Energy Productivity	Improving the energy productivity of buildings requires both the widespread use of currently available energy-efficient technologies and practices, and the development of next generation technologies.
Buildings Energy Productivity Financing	Significant changes to financing mechanisms and market recognition of the value of energy productivity are required to ensure that energy productivity-enabling technology is used by businesses and households. This includes addressing real or perceived risk to the use and deployment of these technologies, which can immediately and adversely impact the cost of financing.
Smart Manufacturing	Sensors and other information and communications technology (ICT) will allow industries better control over their processes and improved energy management of their buildings.
Transportation	Increasing the energy productivity of moving goods and people relies on developing and deploying new technologies that increase vehicle efficiency, increasing options for mass transit, and better integrating transportation needs with the built environment to reduce the demand for motorized transport.
Water Infrastructure	Reducing energy consumption at water and waste water treatment plants and in water conveyance and distribution systems involves three actions: 1) improving energy efficiency and demand response; 2) implementing emerging technologies and processes; and 3) deploying energy recovery and generation technologies.

Renewable Energy's Role in Growing Energy Productivity

To calculate the primary energy of electricity generated from noncombustable renewable energy sources (i.e., hydroelectric, geothermal, solar, and wind), the EIA assumes a heat rate equal to the average heat rate of electricity generated from fossil fuels. The energy productivity analysis for the Roadmap instead uses the heat content of electricity, which is approximately one-third the value of the fossil fuel average heat rate, in its primary energy accounting. This approach is consistent with International Energy Agency accounting of primary energy production,[1] and it was chosen to avoid ascribing transformation losses where they do not exist in electricity production from solar, wind, and other noncombustable renewables. The effect is that replacing fossil generation with generation from noncombustable renewables can improve energy productivity, although this was not a focus of the analysis performed for this Roadmap.

1 OECD, IEA, and Eurostat, Energy Statistics Manual, (Paris: OECD, 2005), accessed July 2015, http://www.iea.org/publications/freepublications/publication/statistics_manual.pdf.

2.1 Government

Action from all levels of government is necessary to accelerate energy productivity. The identified strategies recognize government's own energy use, as well as interactions and responsibilities each level of government has with respect to businesses and private citizens.

2.1.1 FEDERAL GOVERNMENT

Throughout the Accelerate Energy Productivity 2030 meetings, stakeholders emphasized ways the federal government, through a range of policies and programs, can drive increases in U.S. energy productivity. While federal agencies are advancing energy productivity across different sectors of the U.S. economy through existing programs, policies, and proposals for innovative new strategies, they have the potential to do even more. For example, federal minimum efficiency standards for appliances and equipment cover the vast majority of energy use in buildings including 88 percent of all residential energy use, 77 percent of all commercial energy use, and 26 percent of industrial energy use. The standards promulgated by DOE since January 2009 will cumulatively save over 39 quadrillion Btu of energy by 2030. As an additional example, the 2015 Clean Power Plan is expected to drive energy efficiency across states, resulting in a 7 percent reduction in electricity demand by 2030.[28]

The federal government can play a role in promoting energy productivity strategies in five areas: (1) supporting the R&D of new technologies and strategies; (2) using regulatory programs to secure energy and cost savings; (3) setting

28 "Fact Sheet: Energy Efficiency in the Clean Power Plan", United States Environmental Protection Agency, last updated August 20, 2015, http://www2.epa.gov/cleanpowerplan/fact-sheet-energy-efficiency-clean-power-plan.

the financial foundation through revised tax policies; (4) identifying and reducing barriers to the adoption of innovative, proven strategies; and (5) leading by example in adopting and deploying new technologies and strategies in its own operations. Actions taken by the federal government contribute to all six energy productivity wedges:

Smart Energy Systems
Technologies for Buildings Energy Productivity
Financing for Buildings Energy Productivity
Water Infrastructure
Smart Manufacturing
Transportation

2.1.1.1 Investing in Long-Term Energy Productivity: Research and Development

The federal government has an established role in conducting and supporting long-term R&D—the fundamental seed of innovation. This is a vital role because, as the Congressional Budget Office states in its 2014 report, *Federal Policies and Innovation*[29], "Innovation is a central driver of economic growth in the U.S. Workers become more productive when they can make use of improved equipment and processes, and consumers benefit when new goods and services become available or when existing ones become better or cheaper—although the transition can be disruptive to established firms and workers as new products and processes supersede old ones. Innovation produces some benefits for society from which individual innovators are not able to profit, and, as a result, those innovators tend to underinvest in such activity. Policymakers endeavor to promote innovation to compensate for that underinvestment. The federal government influences innovation through two broad channels: spending and tax policies, and the legal and regulatory systems." The report adds, "Because the effects of innovation on the economy can be difficult to measure, economists typically use the growth in total factor productivity (TFP) as a proxy. Growth in TFP is defined as the growth of real output that is not explained by increases in the amount of labor and capital—typically physical structures and equipment used in production, along with intangible capital such as computer software and research and development (R&D)." The more efficient use of physical resources, such as energy, can also translate into gains in TFP. For example, in its *2014 Global R&D Funding Forecast*, Battelle projected a 1.2 percent decline in U.S. investment in aerospace, defense, and security R&D.[30] To ensure continued increases in U.S. energy productivity through 2030 and beyond, federal R&D will be essential to continuing to advance the technical potential and lowering the costs of productivity-enabling technologies. The following are a few key areas of technology R&D that will help achieve the goal.

29 United State Congressional Budget Office, Federal Policies and Innovation (Washington, D.C.: U.S. Congressional Budget Office, 2014), accessed July 2015, http://www.cbo.gov/publication/49487.

30 Martin Grueber and Tim Studt, 2014 Global R&D Funding Forecast (Columbus, OH: Battelle and R&D Magazine, 2013), accessed July 2015, http://www.battelle.org/docs/tpp/2014_global_rd_funding_forecast.pdf.

2.1.1.1.1 Transportation Technologies

The development and deployment of technologies that displace fossil-based transportation fuels or reduce fuel consumption are critical to doubling energy productivity. Federal efforts in vehicle technology R&D span eight agencies. Areas of work include light-weight materials; next-generation aircraft configurations; alternative fuels and lubricants; hybrid propulsion systems; batteries and energy storage; electrical power management between vehicles and the grid; afloat power systems; locomotive engine efficiency; exhaust emissions reduction; vehicle automation; and baseline safety performance of electric vehicles. The fiscal year (FY) 2016 budget requests $1.3 billion for vehicle technology R&D (e.g., automobiles, aircraft, and locomotives), 95 percent of which is divided across the agencies that have transportation programs, such as DOE, DOD, and the National Aeronautics and Space Administration (NASA).[31]

DOE's investments in hybrid and electric vehicle technologies have helped drivers save one billion gallons of gasoline between 1999 and 2012, and they are projected to save another billion gallons by 2022, in total saving consumers $7.3 billion from 1999 through 2022.[32]

Beyond electric and hybrid vehicles, DOE investment in advanced combustion engines has drastically improved the efficiency of cars on the road. A 2010 study estimates that between 1995 and 2007, DOE-supported R&D on advanced combustion engines saved 17.6 billion gallons of diesel fuel, which is equivalent to a 1 percent reduction in total crude oil imports to the United States over those twelve years.[33] The DOE's SuperTruck Initiative, which aims to increase tractor-trailer efficiency by 50 percent over baseline models by 2015, has demonstrated a vehicle that increases freight efficiency by 115 percent and saves $20,000 per year on fuel costs.[34] Federal policies incentivizing the conversion of all Class 8 vehicles[35] into "SuperTrucks" could save the United States $30 billion in annual fuel costs.[36]

31 Executive Office of the President Office of Management and Budget, Government-Wide Funding for Clean Energy Technology (Washington, D.C.: The White House, 2015), accessed July 2015, https://www.whitehouse.gov/sites/default/files/omb/budget/fy2016/assets/fact_sheets/government-wide-funding-for-clean-energy-technology.pdf.

32 Albert N. Link, Alan C. O'Connor, Troy J. Scott, Sara E. Casey, Ross J. Loomis, and J. Lynn Davis, Benefit-Cost Evaluation of U.S. DOE Investment in Energy Storage Technologies for Hybrid and Electric Cars and Trucks (Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, 2013), accessed July 2015, http://www1.eere.energy.gov/analysis/pdfs/2013_bca_vto_edvs.pdf.

33 Albert N. Link, Retrospective Benefit-Cost Evaluation of U.S. DOE Vehicle Combustion Engine R&D Investments: Impacts of a Cluster of Energy Technologies (Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, 2010), accessed July 2015, http://www1.eere.energy.gov/analysis/pdfs/advanced_combustion_report.pdf.

34 "SuperTruck Initiative Partner Improves Class 8 Truck Efficiency by 115%," U.S. Department of Energy, last modified June 23, 2015, http://energy.gov/eere/success-stories/articles/supertruck-initiative-partner-improves-class-8-truck-efficiency-115.

35 A Class 8 vehicle has a gross vehicle weight of more than 33,000 pounds. See "Vehicle Weight Classes & Categories," U.S. Department of Energy Alternative Fuels Data Center, accessed July 2015, http://www.afdc.energy.gov/data/10380.

36 The White House, Improving the Fuel Efficiency of American Trucks: Bolstering Energy Security, Cutting Carbon Pollution, Saving Money and Supporting Manufacturing Innovation (Washington, D.C.: The White House, 2014), accessed July 2015, https://www.whitehouse.gov/sites/default/files/docs/finaltrucksreport.pdf.

2.1.1.1.2 Building Technologies

R&D on next-generation building technologies will lead to advances in end uses representing the majority of building energy consumption, including efficient and cost-competitive lighting, heating and cooling technologies, and windows that decrease energy demand, reduce energy costs for consumers, and improve comfort. DOE also invests in whole-building R&D that demonstrates how new energy-efficient technologies can function together to create an efficient system and achieve greater overall energy bill savings for families and businesses. DOE is also performing applied research on methods to reduce U.S. building-related energy use in existing homes.

As part of the American Recovery and Reinvestment Act of 2009 (ARRA), DOE initiated the Better Buildings Neighborhood Program to both accelerate the adoption of energy-efficient technologies in buildings and generate employment and economic activity during the worst economic crisis in a generation. Between 2010 and 2012, the program created over 4,200 jobs, generated over $155 million in personal income, and saved nearly 1.4 trillion Btu of energy. The standards finalized since the inception of the program are estimated to save 127 quads of energy and offer consumers utility bill savings of $1.8 trillion by 2030.

2.1.1.1.3 Manufacturing Technologies

Development of advanced materials for solar energy conversion, refrigeration systems, and reduced vehicle component mass (i.e., "lightweighting") carry significant potential for improving U.S. energy productivity, through both the use of the materials in U.S. products and the increased global competitiveness that would be realized by developing and manufacturing them in the United States. As an FY 2016 key focus area of DOE's Clean Energy Manufacturing Initiative, DOE offices will collaborate in a crosscutting advanced materials development acceleration effort across the Department. One such effort is the recently announced Clean Energy Manufacturing Innovation Institute on Smart Manufacturing. Smart Manufacturing represents an emerging opportunity faced broadly by the U.S. manufacturing sector to merge information and communications technologies with the manufacturing environment for the real-time management of energy, productivity, and costs in American factories all across the country. Smart Manufacturing was recently identified by private sector and university leaders in the White House's Advanced Manufacturing Partnership 2.0 as one of the highest priority manufacturing technology areas in need of federal investment.

The most recent analysis of DOE's manufacturing technology R&D estimated that in 2009, technologies developed with DOE's support were responsible for saving over 53 trillion Btu. In addition to these energy savings, industrial facility management programs focused on energy-efficient production were able to save 35 trillion Btu and helped businesses save $218 million in energy cost.[37] In addition to saving energy, these technologies allow manufacturers to increase productivity, reduce resource consumption, decrease emissions, and enhance product quality, making U.S. manufacturers more competitive globally.

2.1.1.2 Securing Energy Productivity: Performance Information and Product Standards

To ensure widespread access to productivity gains from continuing technological advances, the federal government sets energy performance standards for many types of appliances and equipment. Efforts to gain consensus between manufacturers, consumers and other stakeholders, federal agencies (including DOE, EPA, and Department of Transportation (DOT)) have established market-based programs and finalized rules to promote efficient products. DOE's appliance standards program sets minimum energy efficiency standards for approximately 60 categories of appliances and equipment used in homes, businesses, and other applications. The ten energy efficiency standards DOE finalized in 2014 alone will save U.S. families and businesses an estimated $67 billion in electricity bills through 2030 and will reduce U.S. energy use by nearly 4.9 quads per year. DOE also determines mandatory efficiency requirements for new federal, commercial, and residential buildings and develops energy efficiency standards for manufactured homes.[38]

In the transportation sector, fuel economy and greenhouse gas emission standards for light-duty vehicles finalized in 2010 and 2012 by EPA and DOT are projected to save families more than $1.7 trillion in fuel costs.[39] EPA and DOT have also proposed standards to further improve fuel economy in heavy-duty vehicles that could reduce fuel costs by $170 billion.[40]

The federal government also secured energy productivity gains by partnering with industry to voluntarily identify energy-efficient projects. The ENERGY STAR® program now features 16,000 partners from across every sector of the U.S. economy, with 70 different product categories and estimated customer savings of nearly $300 billion.[41]

The federal government has the ability to continue its work convening industry experts to develop recognized standards for how energy savings are calculated from a wide variety of measures. This will help ensure that policymakers, financiers, and customers can be confident that investments supporting energy productivity will reliably reduce energy

37 U.S. Department of Energy Industrial Technologies Program, Industrial Technologies Program: Summary of Program Results for CY 2009 (Washington, D.C.: U.S. Department of Energy, 2009), accessed July 2015, http://www1.eere.energy.gov/manufacturing/about/pdfs/impacts2009_full_report.pdf.

38 U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, "Regulations & Rulemaking", last updated July 28, 2014, https://www.energycodes.gov/regulations.

39 U.S. Environmental Protection Agency, EPA and NHTSA Set Standards to Reduce Greenhouse Gases and Improve Fuel Economy for Model Years 2017-2025 Cars and Light Trucks, EPA-420-F-12-051 (Washington, D.C.: U.S. Environmental Protection Agency, 2012), accessed July 2015, http://www.epa.gov/otaq/climate/documents/420f12051.pdf.

40 U.S. Environmental Protection Agency, Cutting Carbon Pollution, Improving Fuel Efficiency, Saving Money, and Supporting Innovation for Trucks, EPA-420-F-15-900 (Washington, D.C.: U.S. Environmental Protection Agency, 2015), accessed July 2015, http://www.epa.gov/otaq/climate/documents/420f15900.pdf.

41 "About ENERGY STAR," Energy STAR, accessed July 2015, http://www.energystar.gov/about.

use and save money. The *Quadrennial Energy Review* (QER) released in early 2015 recommended that DOE accelerate the development of uniform methods for measuring energy savings and promote widespread adoption of these methods in public and private efficiency programs.[42] This effort will reduce information barriers to efficiency investments, making it easier for consumers to reduce their energy bills.

2.1.1.3 Setting the Financial Foundation for Energy Productivity: Tax Policy

Tax policy can be a powerful instrument for the federal government to influence decision makers and transform the economy. Taxes may discourage individuals and business from actions that have negative economic and environmental consequences, while tax credits can encourage outcomes, such as private-sector R&D or capital investments, with positive effects for society. Smart, well-directed national tax policy is a tool the federal government could further employ if the United States is to double energy productivity by 2030. Specific examples follow for households and private-sector R&D. As proposed, the FY 2016 Federal budget includes research and clean energy incentives, including the Research and Experimentation Tax Credit, the renewable energy Production Tax Credit, and the Investment Tax Credit.[43]

2.1.1.3.1 Tax Policy for Households

Individual tax credits for residential energy efficiency and passive solar investments can increase the adoption of technologies that will reduce household energy use beyond what minimum efficiency standards and building codes require. Federal tax incentives have been shown to be successful in transforming the efficiency of residential appliances and new construction. Between 2006 and 2009, a targeted tax credit for builders aimed at increasing the amount of energy-efficient new construction was able to quadruple the number of homes built that are twice as efficient as the required building energy code. Another targeted tax credit for manufacturers was instrumental in doubling the market share of energy-efficient clothes washers in just two years.[44]

A variety of federal tax credits is available for retrofit investments in energy-efficient and clean energy technologies, specifically geothermal heat pumps. However, these tax credits are available only for owner-occupied housing and cannot be claimed for rental properties, which constitute over 33 percent of households.[45] Tax credits that include rental properties could spur a transformation similar to what is occurring in owner-occupied housing. This tax credit could be combined with informational programs, including

42 U.S. Department of Energy, Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure (Washington, D.C.: U.S. Department of Energy, 2015), accessed July 2015, http://energy.gov/sites/prod/files/2015/07/f24/QER%20Full%20Report_TS%26D%20April%202015_0.pdf.

43 Office of Management and Budget, Fiscal Year 2016 Budget of the U.S. Government (Washington, D.C.: U.S. Government Printing Office, 2015), accessed July 2015, https://www.whitehouse.gov/sites/default/files/omb/budget/fy2016/assets/budget.pdf.

44 Rachel Gold and Steven Nadel, Energy Efficiency Tax Incentives, 2005–2011: How Have They Performed? (Washington, D.C.: American Council for an Energy-Efficient Economy, 2011), accessed July 2015, http://aceee.org/sites/default/files/pdf/white-paper/Tax%20incentive%20white%20paper.pdf.

45 U.S. Census Bureau, 2009-2013 5-Year American Community Survey, accessed July 2015, http://www.census.gov/programs-surveys/acs/data.html.

policies that require building owners to disclose energy use to further incentivize equipment upgrades in rental properties.

2.1.1.3.2 Tax Policy for Private-Sector R&D

The federal government could support the development of advanced manufacturing through tax credits. One example of such a proposal is from the President's Council of Advisors on Science and Technology in 2011 that recommended reforming corporate income taxes and permanently extending and increasing the R&D tax credit.[46]

2.1.1.3.3 Tax Policy for Clean Energy Technologies

Stable and refundable tax credits for the production of renewable energy could provide a strong, consistent incentive to encourage investments in renewable energy sources such as wind and solar, create jobs, and support U.S. companies. These new investments, in addition to increased generation of electricity from noncombustible renewables, represent potential gains in energy productivity for the overall economy. Conversely, cyclic or unpredictable tax credits can have an adverse effect on the development of renewable energy. Additionally, the federal government can pursue new tax credits for installation of alternative fuel equipment. Customers may be more likely to adopt electric vehicle technology with faster charging, but direct current (DC), fast-charging technology is currently expensive. As is done with the amenity model where businesses provide no-cost chargers to attract customers, the government could provide tax incentives to businesses that install fast-charging technology, especially during new construction. In all cases, the stability and predictability of renewable energy tax policy is key to its effectiveness.

2.1.1.4 Workforce Training

Some DOE programs, such as the Industrial Assessment Center (IAC) program[47] and the Solar Ready Vets program,[48] support the type of workforce training that will be integral to meeting the energy productivity goal. The federal government should continue and expand on its partnerships with community and technical colleges, universities, and trade organizations to advance curricula and skills for training the next generation of leaders in energy productivity and clean energy manufacturing.

In September 2014, DOE's SunShot Initiative launched the Solar Ready Vets program to connect the nation's skilled veterans with the solar energy industry, preparing them for careers as solar photovoltaic (PV) system installers, sales representatives, system inspectors, and in other industry-related occupations. Solar Ready Vets trains active military personnel—who are

46 President's Council of Advisors on Science and Technology, Report to the President on Ensuring American Leadership in Advanced Manufacturing (Washington, D.C.: The White House, 2011), accessed July 2015, https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-advanced-manufacturing-june2011.pdf.

47 "Industrial Assessment Centers (IACs)," U.S. Department of Energy, accessed July 2015, http://energy.gov/eere/amo/industrial-assessment-centers-iacs.

48 "Solar Ready Vets," U.S. Department of Energy, accessed July 2015, http://energy.gov/eere/sunshot/solar-ready-vets.

"transitioning military" status—within a few months of leaving military service and becoming veterans. The initiative is enabled by the DOD's SkillBridge initiative, which allows exiting military personnel to pursue civilian job training, employment skills training, apprenticeships, and internships up to six months prior to their separation.

DOE's IACs train the next generation of energy-savvy engineers, more than 60 percent of whom pursue energy-related careers upon graduation. IAC assessments are in-depth evaluations of a facility conducted by engineering faculty with junior and senior college students, and graduate students from participating universities. Small-and medium-sized manufacturers may be eligible to receive a no-cost assessment provided by IACs. Over 16,000 IAC assessments have been conducted. Typically, IACs identify more than $130,000 in potential annual savings opportunities for every manufacturer assessed, nearly $50,000 of which is implemented during the first year following the assessment.

2.1.1.5 Implementing Strategies for Energy Productivity: Demonstrations and Leading by Example

The federal government is the single largest consumer of energy in the U.S. economy, but its use of 0.96 quadrillion Btu in FY 2014 was the lowest since tracking began in 1975.[49] Other federal building and facility accomplishments include reducing Scope 1 and 2 greenhouse gas emissions by 17.4 percent, using 8.8 percent renewable electricity, reducing potable water use by 21 percent,[50] and reducing the energy use per square foot of building space by 21 percent. By expanding its use of proven strategies to improve energy efficiency, the federal government can provide public services at lower cost, saving taxpayer dollars and helping realize the benefits of doubled energy productivity. Through Executive Order 13693, President Obama directed federal agencies to reduce energy intensity (Btu/gross square foot) in federal buildings by 2.5 percent per year from an FY 2015 baseline through FY 2025.[51] Executive vehicle fleets also have been directed to achieve maximum fuel efficiency.[52]

The federal government has expanded and extended the Presidential Performance Contracting Challenge—one tool to achieve the savings goal—to deploy $4 billion in energy-saving and renewable energy projects at government facilities through 2016. DOE's FEMP will continue to support the challenge by working with agencies to meet the $4 billion goal and by helping agencies continue to accelerate their use of performance contracts to meet future energy investment needs and goals. FEMP will also share and rely on best practices from the challenge to partner with other government and private-sector stakeholders and partners to accelerate their use of performance contracts.[53]

49 "Federal Comprehensive Annual Energy Performance Data," U.S. Department of Energy, accessed July 2015, http://www.energy.gov/eere/femp/federal-facility-annual-energy-reports-and-performance.

50 Chris Tremper, "Federal Progress toward Energy/Sustainability Goals" (presented June 10, 2014), accessed July 2015, http://energy.gov/sites/prod/files/2015/06/f22/facility_sustainability_goals.pdf.

51 Executive Order 13693—Planning for Federal Sustainability in the Next Decade, 80 Fed. Reg. 57 (March 25, 2015), accessed July 2015, http://www.gpo.gov/fdsys/pkg/FR-2015-03-25/pdf/2015-07016.pdf.

52 The White House Office of the Press Secretary, "Presidential Memorandum--Federal Fleet Performance," news release, May 24, 2011, https://www.whitehouse.gov/the-press-office/2011/05/24/presidential-memorandum-federal-fleet-performance.

53 "Federal Energy Management Program," U.S. Department of Energy, accessed July 2015, http://www.energy.gov/eere/femp/federal-energy-management-program.

For technologies and systems that have the potential to reduce energy costs but require further demonstration before becoming market-ready, the federal government leverages its full portfolio of facilities as testbeds for innovation. The General Services Administration's Green Proving Ground program leverages government real estate and facilities to evaluate sustainable building technologies in the pre- or early-commercial stages of development and to provide recommendations on their deployment.[54] DOD's Installation Energy Test Bed program features projects to demonstrate emerging technologies for building efficiency, energy management, smart microgrids, energy storage and distributed renewable generation. These projects will help identify technologies that can be adopted at government and private facilities across the United States while simultaneously helping DOD reduce its facility energy bill, which totals roughly $4 billion per year.[55]

Programs across several agencies provide opportunities to deploy strategies to improve energy productivity:

- **Reducing Energy Costs in Multifamily Homes:** The U.S. Department of Housing and Urban Development provides the $25-million Multifamily Energy Innovation Fund, which enables affordable housing providers, technology firms, academic institutions, and philanthropic organizations to test new approaches to delivering cost-effective, residential energy efficiency upgrades.[56]
- **Improving Energy Productivity in Rural Communities:** As soon as the third quarter of 2015, the U.S. Department of Agriculture's Rural Utilities Service will have finalized a proposed update to its Energy Efficiency and Conservation Loan Program to provide up to $250 million for rural utilities to finance efficiency investments by businesses and homeowners across rural America.[57] The Department of Agriculture is also streamlining its Rural Energy for America Program to provide grants and loan guarantees directly to agricultural producers and rural small businesses for energy efficiency and renewable energy systems.[58] These programs will help reduce energy costs for rural households and businesses, allowing savings to be reinvested in local communities.
- **Improving Energy Productivity in Transportation:** Plug-in electric vehicles (PEVs), including plug-in hybrid electric vehicles (PHEVs) and all-electric vehicles (EVs), offer the potential of lower primary energy than conventional gasoline vehicles. The adoption of PEVs would benefit from introducing and refining new technologies for batteries, drivetrains, and other vehicle components. Expanding the number of charging stations and related infrastructure would also promote adoption of PEVs as well as enable new electricity supply and demand options by integrating PEVs with building energy use.
- **DOE's Workplace Charging Challenge:** This program, which seeks a tenfold increase in the number of employers providing workplace-charging stations, estimates that the employees of participating businesses are twenty times as

54 "What is GPG?" U.S. General Services Administration, last modified August 12, 2015, http://www.gsa.gov/portal/category/102575.

55 "Installation Energy Test Bed," The Strategic Environmental Research and Development Program and The Environmental Security Technology Certification Program, accessed July 2015, https://www.serdp-estcp.org/Featured-Initiatives/Installation-Energy.

56 "Multifamily Energy Innovation Fund," U.S. Department of Housing and Urban Development, accessed July 2015, http://portal.hud.gov/hudportal/HUD?src=/program_offices/housing/mfh/presrv/energy.

57 Executive Office of the President, The President's Climate Action Plan (Washington, D.C.: The White House, 2013), accessed July 2015, https://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf.

58 "Rural Energy for America Program Renewable Energy Systems & Energy Efficiency Improvement Loans & Grants," U.S. Department of Agriculture Rural Development, accessed July 2015, http://www.rd.usda.gov/programs-services/rural-energy-america-program-renewable-energy-systems-energy-efficiency.

likely to drive a PEV as the average worker. As of June 2014, the partner charging stations provided an estimated 6.7 million kilowatt-hours (kWh) annually or approximately 0.8 percent of estimated light-duty vehicle electricity use in 2014.

2.1.2 STATE GOVERNMENT

State governments possess a wide range of tools to drive energy productivity in state operations as well as in the private sector, and they can play an important role in supporting and leveraging local government-led efforts. The *Roadmap* highlights state strategies for increasing the energy productivity of buildings and transportation systems, enabling the smart grid, and improving energy productivity financing mechanisms. Workforce development programs offered by state universities and technical colleges are discussed in Section 2.5. Actions taken by state governments contribute to all six energy productivity wedges:

Smart Energy Systems
Technologies for Buildings Energy Productivity
Financing for Buildings Energy Productivity
Water Infrastructure
Smart Manufacturing
Transportation

2.1.2.1 Energy Efficiency Portfolio Resource Standards

Where appropriate, energy productivity improvements can come from state implementation of energy efficiency resource standards or energy efficiency portfolio standards. In general, portfolio standards establish performance targets for the amount of energy efficiency improvements achieved, which then allow market forces to identify the most cost-effective way(s) to achieve the targets. Currently, 26 states have an energy efficiency portfolio standard.[59]

2.1.2.2 Energy Productivity Financing

States can reduce barriers to business and household adoption of energy productivity technology by focusing on strategies to improve financing mechanisms.[60] One such strategy is to develop secondary markets for energy efficiency

59 Counts for both types of portfolio standards were obtained from http://www.dsireusa.org/. The figure for energy efficiency portfolio standards includes states with voluntary or underfunded goals, such as those for Delaware, Florida, Missouri, and Virginia. Other states have repealed (Indiana), have frozen (Ohio), or are considering repealing their energy efficiency portfolio standards (Michigan). Conversely, other states, such as Maryland and Pennsylvania, have extended theirs.

60 State and Local Energy Efficiency Action Network, Energy Efficiency Financing Program Implementation Primer (Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, 2014), accessed July 2015, https://www4.eere.energy.gov/seeaction/system/files/documents/financing_primer_0.pdf.

loans, such as those provided under the Warehouse for Energy Efficiency Loans (WHEEL) program.[61] WHEEL is a public-private partnership sponsored by states, local governments, and utilities. It uses public funds and private capital to provide funding for energy improvement projects.

Other financing strategies involve using public funding to unlock private capital. For example, Connecticut's Property Assessed Clean Energy (C-PACE) program has used property assessed clean energy (PACE) financing.[62] Revolving loan funds are another source of financing for energy productivity. They offer long-term, low-interest rate financing for initiatives such as building efficiency retrofits and job creation. Revolving loan funds also support on-bill repayment, ESPCs, and public-private partnerships. Currently, 79 revolving loan funds programs across 44 states represent over $2 billion in financing.[63] Utilities, businesses, and lending institutions also have significant potential to improve access to financing for energy productivity investments, and these are discussed in subsequent sections.

The Keystone Home Energy Loan Program (Keystone HELP) is an example of a specialized loan program for improvements in home energy efficiency. Under the program, which is supported by the Pennsylvania Treasury Department and the Pennsylvania Department of Environmental Protection, homeowners seeking financing for their energy efficiency and renewable energy related home improvements can apply for low fixed-rate loans with repayment periods of up to ten years.[64] Under the program, homeowners have financed over $63 million in projects since the program began in 2006, and they have saved $2.3 million annually on utility bills.[65]

Finally, regulators can more effectively incentivize utility energy and water efficiency programs using a three-pronged approach that includes cost recovery, throughput incentives, and earnings opportunities.[66] Cost recovery options, such as escrow and rate riders, enable utilities to recover energy efficiency costs roughly when they occur. Throughput incentives address reduced energy and water sales from efficiency by decoupling sales from revenues. Earning opportunities, such as a share of energy and water efficiency program net benefits, could be provided to utilities as incentives for achieving energy efficiency program success.

61 "Warehouse for Energy Efficiency Loans (WHEEL)," National Association of State Energy Officials, accessed July 2015, http://www.naseo.org/wheel.

62 "C-PACE," Connecticut Green Bank, accessed July 2015, http://www.c-pace.com/.

63 National Association of State Energy Officials, State Energy Revolving Loan Funds (Arlington, VA: National Association of State Energy Officials, 2013), accessed July 2015, http://www.naseo.org/Data/Sites/1/documents/selfs/state_energy_rlf_report.pdf.

64 "Financing Program," EnergyLoan, accessed July 2015, http://www.energyloan.net/info/financing-program.

65 "Keystone Help," Pennsylvania Treasury, accessed July 2015, http://www.patreasury.gov/website-redesign/earn/keystonehelp/.

66 Dan York and Martin Kushler, The Old Model Isn't Working: Creating the Energy Utility for the 21st Century (Washington, D.C.: American Council for an Energy-Efficient Economy, 2011), accessed July 2015, http://aceee.org/files/pdf/white-paper/The_Old_Model_Isnt_Working.pdf.

FINANCING SUCCESS STORY

Massachusetts Leads by Example

The Commonwealth of Massachusetts, a DOE Better Buildings Challenge partner, in 2007 set ambitious energy savings targets for the Commonwealth to reduce energy use intensity 20 percent by 2012 and 35 percent by 2020, based on 2004 levels. However, in the wake of the national economic downturn in 2008, a steep decline in project financing from banks and energy service companies stranded a three-year pipeline of $237 million in energy efficiency projects. In 2010, Massachusetts responded by creating an innovative financing model called the Clean Energy Investment Program (CEIP). The program invests in projects using bond funding which is repaid from the energy savings generated by the projects. The bonds are obtained at the same time as general obligation bonds; however, Massachusetts leverages this low-cost financing without hitting the Commonwealth's general obligation debt limits.

In four years, CEIP mobilized 28 projects for more than $136 million across 15 million square feet of Commonwealth buildings with projected annual savings of $14.3 million over the life of the bond terms, which can often equal or sometimes exceed 20 years. These projects represent greater Commonwealth investment in energy efficiency than in the previous 25 years. The Commonwealth also has a pipeline of approximately $260 million for 74 ready-to-go energy efficiency projects, which will generate $22 million in annual savings over the terms of the contracts, typically 10–20 years. Massachusetts maintained the top spot on the American Council for an Energy-Efficient Economy's State Energy Efficiency Scorecard for four consecutive years, and it attributes its success in part to operationalizing its energy efficiency policies for its facilities via CEIP program financing. The Commonwealth plans to make CEIP financing available to additional energy retrofit initiatives.

The Commonwealth of Massachusetts is now working with 42 separate Commonwealth agencies to track, measure, and report energy savings annually. In all, 29 of the 42 agencies have seen energy reductions from the baseline, demonstrating that energy reductions are broad and have occurred across the majority of the Commonwealth's portfolio. In 2014, Massachusetts reduced energy use intensity by 7 percent as part of CEIP and other efforts, bringing total savings to 16 percent across its entire 65 million square feet portfolio of Commonwealth-owned buildings.

Reference to a non-federal entity does not constitute an endorsement on the part of DOE or the U.S. government.

2.1.2.3 Combined Heat and Power

States have an important role in supporting the installation of new combined heat and power (CHP) capacity, a significant enabler of increased energy productivity. Achieving the national goal of 40 gigawatts (GW) of new, cost-effective CHP by 2020 would save energy users $10 billion per year, conserve one quad of energy, and result in $40 billion–$80 billion in new capital investment in manufacturing over the course of a decade.[67] States can support CHP installation through several strategies, including folding CHP requirements into energy efficiency portfolio standards (discussed in Section 2.1.2.1), reconsidering standby rate regimes that better align the economics of CHP facilities and utilities, and revising interconnection standards.[68]

The DOE's Advanced Manufacturing Office (AMO) provides CHP Technical Assistance Partnerships (CHP TAPs) that offer market analysis for CHP opportunities, education and outreach on the energy and non-energy benefits of CHP, and technical assistance to help end-users through the project development process. Between fiscal year (FY) 2009 and FY 2013, centers sponsored by the Advanced Manufacturing Office provided technical support to over 590 CHP projects. About 350 of those projects received "Technical Site Evaluations" (either alone or in conjunction with other support) while the rest were provided with other types of technical assistance, often on multiple occasions. Of those projects, more than 190 are currently under development or online with a total capacity of 1.54 GW.[69]

2.1.2.4 Smart Regional Transportation Solutions

Improving the energy productivity of regional transportation systems involves increasing both the energy efficiency of transportation modes and the economic benefits of transportation services. Transportation options that are more energy productive, such as multi-modal transportation options, can benefit the movement of goods and people. State transportation planning (as well as land use planning) provides opportunities to directly influence energy productivity and increase collaboration of state governments and communities. States can also provide support for electric vehicles, which may reduce primary energy use relative to conventional gasoline vehicles and which may have economic and other benefits. Opportunities for regional transportation organizations to incentivize reduced vehicle energy use are discussed in Section 2.1.3.

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67 U.S. Department of Energy Advanced Manufacturing Office, Combined Heat and Power: A Clean Energy Solution, DOE/EE-0779 (Washington, D.C.: U.S. Department of Energy, 2012), accessed July 2015, http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf.

68 State and Local Energy Efficiency Action Network, Guide to the Successful Implementation of State Combined Heat and Power Policies (Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, 2013), accessed July 2015, http://www4.eere.energy.gov/seeaction/system/files/documents/see_action_chp_policies_guide.pdf.

69 Claudia Tighe, "CHP Deployment Program: AMO Technical Assistance Overview," (presented 2014), accessed July 2015, http://energy.gov/sites/prod/files/2014/06/f17/CHP%20Deployment%20Program.pdf.

TRANSPORTATION SUCCESS STORY

Los Angeles County Metropolitan Transportation Authority - Encouraging Consumer Acceptance of Energy Efficiency through Electric Vehicles

The Los Angeles County Metropolitan Transportation Authority (Metro) has a unique function among the nation's transportation agencies. It serves as the transportation planner and coordinator, designer, builder and operator for one of the country's largest, most populous counties. More than 9.6 million people – nearly one-third of California's residents – live, work, and play within its 1,433-square-mile service area. Metro recognizes the importance of energy efficiency, while ensuring that its transit and transportation network continues to be resilient in changing times. In 2011, Metro developed a comprehensive Energy Conservation and Management Plan (Energy Plan) that provides a blueprint for Metro's overall energy management and use. The Energy Plan incorporates elements of the Metro Board-adopted Energy and Sustainability and Renewable Energy Policies. By 2020, Metro's goal is 33 percent renewable energy use, and the agency is well on its way to hitting that target. Metro is now at 25 percent. The emergence of electric vehicles as an alternative type of personal transportation influenced how Metro plans for an integrated multi-modal transportation network. In 2013, Metro deployed, through a California Energy Commission (CEC) funded pilot program, twenty electric vehicle charging stations at five of Metro's park and ride locations. This type of electric vehicle charger network is the first of its kind that is operated and maintained by a transit agency in the United States.

The placement of electric vehicle chargers at Metro park and ride locations was strategic. Charge stations at Metro park and ride facilities provide much needed infrastructure to Plug-In Electric Vehicle (PEV) users, but also provide those users with connectivity to Metro's other modes of transportation. This powerful link enables important consumer behavioral changes by blending two low-carbon transportation options: PEV and public transportation via rail and any of Metro's natural gas fueled buses. Additionally, by placing PEV infrastructure at Metro transit stations, Metro provides visual reinforcement to a large number of potential PEV adopters that there is a charging network readily available. Further, connected through a support network that subscribes EV charger users, collects payments, and provides operations and maintenance support, Metro's electric vehicle charger stations provide a seamless integrated mobility solution.

Using Metro's approach to incorporating EV chargers into its park and ride stations as a fundamental strategy, Southern California Edison has successfully applied for a tariff to fund extensive deployment of electric vehicle chargers across Southern California, ensuring that the transit and electric vehicle nexus continue to be a viable option in avoiding trips and traffic congestion in Southern California roads and highways. Through another CEC grant, Metro is currently expanding its EV charger network to an additional five park and ride locations. It is also leveraging local fiscal year 2016 funding to deploy EV chargers at four rail divisions and 11 bus divisions for workplace charging. Metro will ultimately deploy electric vehicle chargers throughout its system and workplace locations.

Metro continues to explore innovative ideas to ensure energy resiliency, including powering EV chargers with renewable energy sources (such as solar panels connected to deployable storage systems) and using those chargers as a source of emergency power. Metro's procurement to use biomethane as bus fleet fuel (instead of fossil natural gas) will further enhance Metro's greenhouse gas emissions reduction efforts for the Los Angeles region. Metro currently produces carbon credits generated through its dispensing of fossil natural gas. In the future, carbon credits through the use of biomethane and electricity as propulsion power (through its EV chargers and its rail network) can be sold along with Metro's current carbon credits to reinvest in energy efficiency, renewable energy, and energy resilience initiatives.

More information on Metro's EV charger program can be obtained at www.metro.net/ev. Metro's Energy and Resource Management Programs can be obtained at www.metro.net/ecsd.

Reference to any non-Federal entity does not constitute an endorsement on the part of the Department of Energy or U.S. Government

2.1.2.5 Adoption and Enforcement of Building Codes

Building energy efficiency codes provide the foundation for increasing the energy productivity of buildings. Existing codes are estimated to yield cumulative benefits of 44 quadrillion Btu, which is more than twice as much energy as all households in the U.S. use in a year, and $230 billion in customer utility bill savings by 2040.[70] Expanding state adoption of building energy codes,[71] as well as increasing the stringency, enforcement and compliance with the codes themselves, will yield additional energy productivity benefits, while reducing utility bills and increasing customers' comfort within their homes and buildings. Utilities can play important roles in developing and funding building code programs. For instance, utilities provided partial funding for Ohio's Energy Code Ambassadors Program (ECAP). ECAP seeks to increase building code enforcement by directly connecting local code officials with trained, experienced code officials.[72] Washington, with a 2013 compliance rate of 96 percent,[73] partnered with utilities to fund much of its work with building codes.

2.1.3 LOCAL GOVERNMENT

Local governments are critical sources of policies and other strategies for meeting the goal of doubling energy productivity. In addition to setting policies that affect individual businesses and citizen groups, local governments have the opportunity to affect the types of systematic changes necessary to develop energy-productive communities. In particular, land use policy decisions at the local level can unlock energy productivity potential found at the intersection of transportation and the built environment. These decisions can affect how much citizens must spend on energy to support their daily routines, and their impacts last for decades.

Participants in the Accelerate Energy Productivity 2030 regional dialogues confirmed that a multitude of energy productivity actions are available to local leaders, depending on the local characteristics of geography, population density, energy resources, and economy. Characteristics of energy-efficient built environments include building density and mixed-use development (often referred to as "smart growth"), sensitivity to microclimatic factors, and the availability of distributed energy resources. Actions by local governments contribute to all six energy productivity wedges:

70 Livingston, O.V., D.B. Elliott, P.C. Cole, R. Bartlett, Building Energy Codes Program: National Benefits Assessment, 1992 2040 (Richland, WA: Pacific Northwest National Laboratory, 2014), accessed July 2015, https://www.energycodes.gov/sites/default/files/documents/BenefitsReport_Final_March20142.pdf.

71 In home rule states, codes must be adopted by the local government.

72 U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, Achieving Energy Savings and Emission Reductions from Building Energy Codes: A Primer for State Planning (Washington, D.C.: U.S. Department of Energy, 2015), accessed July 2015, https://www.energycodes.gov/sites/default/files/documents/Codes_Energy_Savings_State_Primer.pdf.

73 Northwest Energy Efficiency Alliance. Washington Residential Energy Code Compliance, *Report #E13-251*, prepared by the Cadmus Group, Inc. (Portland, OR: Northwest Energy Efficiency Alliance, 2013), accessed July 2015, http://neea.org/docs/default-source/reports/washington-residential-energy-code-compliance.pdf?sfvrsn=11

Smart Energy Systems
Technologies for Buildings Energy Productivity
Financing for Buildings Energy Productivity
Water Infrastructure
Smart Manufacturing
Transportation

2.1.3.1 Local Ordinances to Facilitate Distributed Generation

Promotion of distributed generation sources (e.g., cogeneration, solar photovoltaics, and wind power) can be an effective lever that local communities can use to improve their energy productivity through increased energy-efficient power generation, transmission, and distribution. Establishing installation targets, creating PACE programs, and implementing property and sales tax incentives can facilitate distributed generation. In addition to creating new ordinances or other policies, local governments can review existing ordinances to determine which, if any, inadvertently hinder distributed generation (e.g., ordinances that may restrict installation of solar photovoltaic systems).

One strategy to encourage the development of distributed generation is for local communities to support solar cooperatives, by which members collectively purchase solar energy systems to achieve discounted installation and equipment costs. Community solar initiatives that have appeared in municipalities across the United States have taken different forms based on the motivation of the members.[74] There may also be opportunities for community-based solar on under-utilized land.

And, local communities can complement ordinances that support the installation of distributed electricity generation by encouraging construction and retrofit of ultra-efficient buildings. Local policies such as permitting and building code enforcement can be instrumental in integrating energy considerations early in project planning. These considerations can include passive solar design and siting and the integration of building designs among architects, engineers, contractors, and developers.

74 The applicability of community solar projects will vary by state. For example, certain state laws may prohibit third-party purchase agreements, which significantly impact the viability of solar for businesses and communities. See Jason Coughlin, Jennifer Grove, Linda Irvine, Janet F. Jacobs, Sarah Johnson Phillips, Leslie Moynihan, and Joseph Wiedman, *A Guide to Community Solar: Utility, Private, and Non-Profit Project Development*, DOE/GO-102011-3189 (Golden, CO: National Renewable Energy Laboratory, 2011), accessed July 2015, http://www.nrel.gov/docs/fy11osti/49930.pdf.

PUBLIC BUILDING SUCCESS STORY

Washington State Drives Energy Efficiency through Benchmarking Public Buildings

The Washington State Department of Commerce's State Energy Office is a leader in providing energy policy support, analysis, and information for the Governor, Legislature, and other stakeholders on key energy efficiency issues. Despite this expertise and strong legislative support, participation in benchmarking public buildings remained extremely low. The majority of public facilities were not benchmarked, and those that were eventually stopped reporting because monthly manual entries were time consuming, there was no compliance enforcement, and there was no apparent value to tracking this consumption data. In early 2014, less than 7 percent of the required benchmarking sites within the state's forty nine executive and small cabinet agencies were populating current data within Portfolio Manager, a free web-based tool created by the State to track and report building energy use.

A second barrier to achieving 100 percent benchmarking compliance was the lack of an internal method to determine how many sites that were required to report benchmarking data actually existed. Because of the way the initial 2009 energy efficiency law was written, large groups of buildings residing on a master -metered campus could be benchmarked as a single site. While that was a logical way to capture data for campuses without having to expend money on sub-meters, it was impossible to track because the State Facility Inventory System did not provide campus groupings.

In 2014, the State Energy office was directed by Executive Order 14-04—the *Washington Carbon Pollution Reduction and Clean Energy Action*—to increase public building efficiency. This order brought together a broad group of agencies that agreed achieving 100 percent benchmarking compliance was a necessary step towards increasing public building efficiency. With support from a U.S. Department of Energy State Energy Program Competitive Awards grant, the State created the Interagency Energy Workgroup and provided dedicated staffing support to address the lack of a centralized system for benchmarking and compliance. This support included the state Department of Enterprise Services and Office of Financial Management, and Washington State University (WSU). The Interagency Energy Workgroup created and promoted a process for increasing energy efficiency in public buildings. However, the lack of current benchmarking data was a key challenge to implementing the overall process, so compiling benchmarking data became a primary objective.

Initial efforts focused on completing benchmarking via a centralized process through partnership with utilities; as a result, benchmarking compliance increased from 7 to 37 percent. After determining that this centralized process was too cumbersome, the State Energy Office led an effort supported by WSU and the Smart Buildings Center to identify exactly how many required "target sites" existed within the state Executive agencies. This effort involved high-level mapping and assumptions using the Facilities Inventory System database to categorize similar WSU campuses and compare those sites to data found within the Portfolio Manager. Several months later, the first "Benchmarking Yardstick" was presented as a rough assessment of compliance, and indicated that approximately 25 percent of required Executive agency sites were benchmarked. This first yardstick was presented to the Governor's Office by the directors of the Department of Commerce and Department of Enterprise Services, creating high-level awareness and further amplifying progress.

With support from the Governor's Office, the Interagency Energy Workgroup expanded its efforts and subsequently hosted a well-attended webinar, created a set of instructions specific to benchmarking, and distributed an Agency Facility Status report. The report identified the buildings or campuses that were required to benchmark, and provided a survey whereby each agency could confirm or correct their campus groupings, building conditioning status, and utility payment. With the survey results in hand, for the first time the State was able to identify that there were 219 Target Sites operated by Executive agencies that were required to be benchmarked. These 219 target sites included energy consumption for over 2,000 individual buildings.

Washington State knew there was inherent value in the ability to evaluate building stocks' energy intensity and track changes in energy consumption over time, but until these recent efforts was unable to obtain the participation needed to make the energy efficiency program as effective as possible. the work undertaken by the Interagency Energy Workgroup allowed Washington State Executive Agencies to increase their benchmarking compliance from less than 7 percent in 2009 to over 80 percent by 2014. Further efforts are underway to perform data quality assessment and data analytics using this new benchmarking data, which can point the State towards the best opportunities for energy efficiency gains—a capability not previously possible.

Reference to a non-federal entity does not constitute an endorsement on the part of DOE or the U.S. government.

2.1.3.2 Building Energy Disclosure Ordinances

Communities typically lack actionable information on how residents use energy to interact with one another and with their built environment. Advancing transparency of building energy use is an important established strategy for accelerating energy efficiency in cities.[75] Ordinances regarding disclosure of building energy use are one way to provide transparency about where, when, and how communities use energy. Atlanta, Austin, New York, Minneapolis, and Philadelphia (see Figure 6) have enacted disclosure ordinances regarding energy use in buildings. All told across the United States, disclosure ordinances covered more than 45,000 properties and 4.3 billion square feet in 2013.[76]

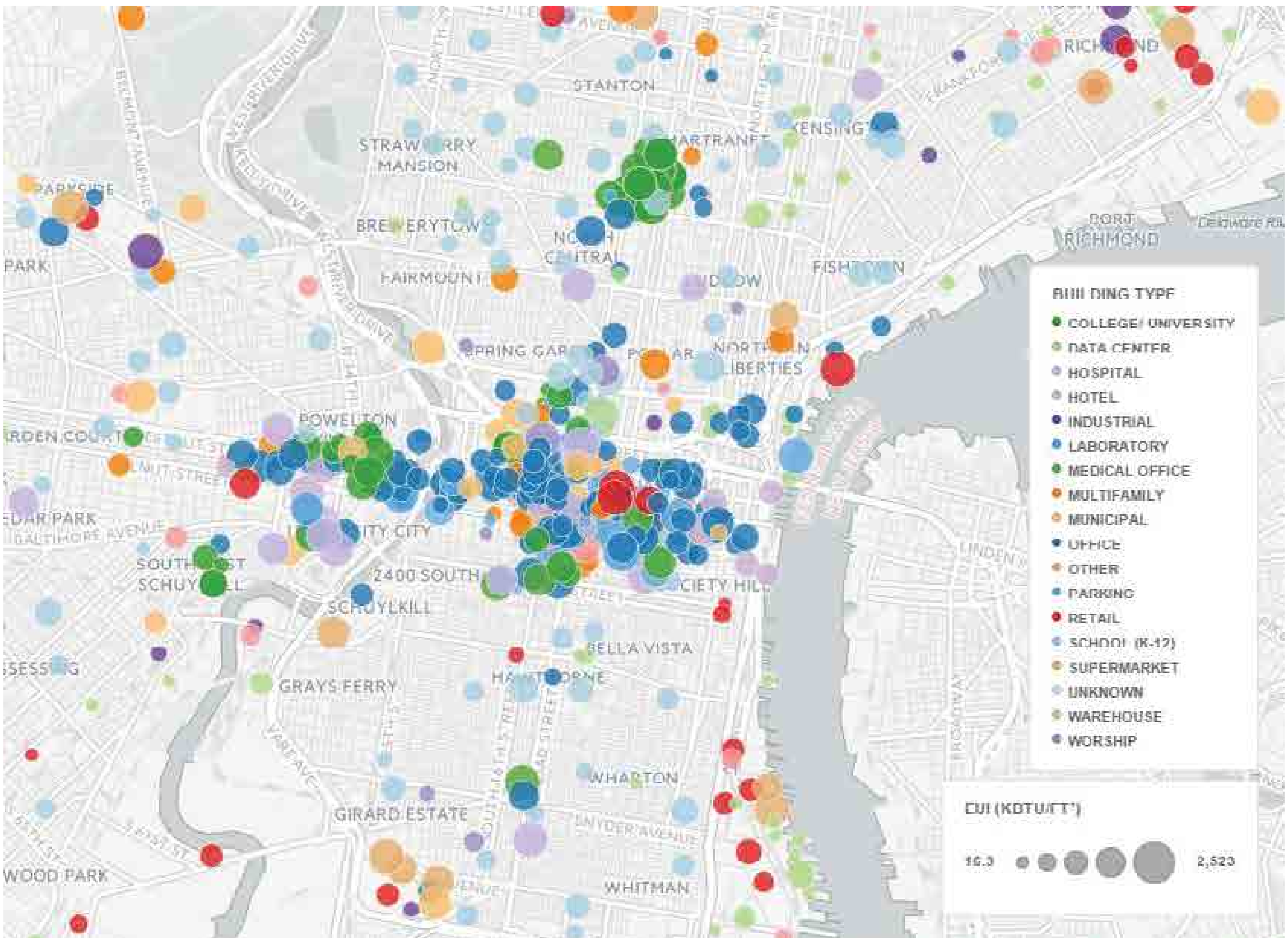

Figure 6. Philadelphia's Building Energy Data Mapping Platform

75 "Frequently Asked Questions," The City Energy Project, accessed July 2015, http://www.cityenergyproject.org/faq/.

76 Andrew Burr, "Building Energy Benchmarking and Disclosure: U.S. Policy Overview" (presented at the U.S. Department of Energy Better Buildings Summit, May 30, 2013), accessed July 2015, http://www1.eere.energy.gov/wip/solutioncenter/pdfs/bbs2013_burr_overview.pdf.

Disclosure of energy data alone has been associated with a 3 percent reduction in utility expenditures.[77] Energy disclosure ordinances help local governments benchmark building energy performance and efficiently target energy productivity improvements. New York City's benchmarking analysis found that buildings serving similar purposes varied in their energy by a factor of three to seven.[78]

Buildings that are more energy productive have higher occupancy levels, and they command higher rental and sales premiums than their less productive counterparts do.[79] By facilitating transparent energy use data and benchmarking, building energy disclosure ordinances can help make communities more economically competitive.

2.1.3.3 Creating Advanced Manufacturing Ecosystems

Local initiatives can help build the foundation for enabling growth of innovative businesses, such as advanced manufacturing. For local policymakers to more effectively foster the growth of new businesses, such as advanced manufacturing, a new type of organizational structure has emerged: the "startup delivery unit." Using a startup delivery unit, which is comprised of a rotating assignment of eight to twelve public- and private-sector employees, local policymakers can think strategically about the talent, infrastructure, capital, and networks required to foster the growth of advanced manufacturing businesses.[80] Successful local policies can focus on establishing enabling structures to meet the needs of entrepreneurs—rather than defining specific resources—and bringing together and managing diverse sets of stakeholders, which include businesses, universities, and multiple levels of government.

Local governments could also look to partnering with other local and state counterparts to expand available resources in order to attract new businesses that provide energy productivity-enabling products or services. This strategy is modeled on efforts to promote entrepreneurship and start-up activity as embodied by Silicon Valley in California. One important feature of successful local partnerships is fostering interaction between entrepreneurs and local colleges and universities. For example, the City of New York challenged top applied science and engineering institutions to propose a new campus situated on city-owned land; the result is Cornell Tech, a partnership between Cornell University and the Technion – Israel Institute of Technology.[81] Other local initiatives for supporting energy innovation clusters include public funding instruments for early-stage businesses and creating a campus for entrepreneurs.

77 Karen Palmer and Margaret Walls, *Does Information Provision Shrink the Energy Efficiency Gap? A Cross-City Comparison of Commercial Building Benchmarking and Disclosure Laws* (Washington, D.C.: Resources for the Future, 2015), accessed July 2015, http://www.rff.org/RFF/Documents/RFF-DP-15-12.pdf.

78 PLANYC, *New York City Local Law 84 Benchmarking Report* (New York: Mayor's Office of Long-Term Planning & Sustainability, 2012), accessed July 2015, http://www.nyc.gov/html/gbee/downloads/pdf/nyc_ll84_benchmarking_report_2012.pdf.

79 Institute for Market Transformation, *Energy Benchmarking and Transparency Benefits* (Washington, D.C.: Institute for Market Transformation, 2015), accessed July 2015, http://www.imt.org/uploads/resources/files/IMTBenefitsofBenchmarking_Online_June2015.pdf.

80 Julian Kirchherr, Gundbert Scherf, and Katrin Suder. (New York: McKinsey & Company, 2014), accessed July 2015, Julian Kirchherr, Gundbert Scherf, and Katrin Suder. Creating growth clusters: What role for local government? (New York: McKinsey & Company, 2014), accessed July 2015, http://www.compete.org/storage/images/uploads/File/PDF%20Files/Creating-growth-clusters-what-role-for-local-government%20(2).pdf.

81 For more information, see tech.cornell.edu.

2.1.3.4 The Local Built Environment-Transportation Nexus

Opportunities to increase energy productivity also exist through improved design of our built environment, which is estimated to affect 65 - 70 percent of energy use.[82] By better matching the ways energy is used for transportation and within buildings to the design of our communities, more productive uses of energy can be uncovered. The relationship between energy use and the built environment is complex and while physical features of a place certainly play a role, energy use may ultimately be determined by human behavior. For this reason, strategies to improve the built environment and transportation policies often require consensus or partnerships between those responsible for publicly owned infrastructure and those responsible for privately owned residential and commercial buildings.[83] *Envision Charlotte* is an example of an initiative that connects local government, utilities, private businesses, and higher education institutions in an effort to drive dramatic reductions in local energy use (20 percent over five years in Uptown Charlotte office buildings) while growing a vibrant economy. Reductions in building energy use are sought through participation in Duke Energy's Smart Energy in Offices program, which provides support for benchmarking of energy use and the identification and implementation of energy efficiency improvements.[84] Over 98 percent of the eligible building area is participating in *Envision Charlotte* programs, and as of 2012, 55 building tenants have committed to meeting the 20 percent reduction goal.[85]

Many other local actions increase the energy productivity associated with existing buildings. The City of Atlanta's Sustainable Home Initiative in the New Economy (SHINE) partners with Georgia Power and the ENERGY STAR® program to offer home energy assessments and rebates for cost-effective energy efficiency retrofits.[86] The SHINE program, along with similar initiatives in the Southeast, was found to be associated with increases of 349 new jobs and nearly $78 million in economic output.[87]

Other opportunities to advance energy productivity include (1) increasing the availability and accessibility of non-motorized transportation, mass transit options, and carpooling and (2) fostering vibrant communities by encouraging density and mixed-use development to reduce the distances between activities. The Transportation Research Board

82 J.O. Lamm, E*nergy in physical planning: a method for developing the municipality master plan with regard to energy criteria*, Document D14:1986 (Stockholm: Swedish Council for Building Research, 1986).

83 William P. Anderson, Pavlos S. Kanaroglou, and Eric J. Miller, "Urban Form, Energy and the Environment: A Review of Issues, Evidence and Policy," *Urban Studies* 33:1 (1996): 7–35, accessed July 2015, http://dx.doi.org/10.1080/00420989650012095.

84 "Smart Energy in Offices," Duke Energy, accessed July 2015, http://www.smartenergyinoffices.com/.

85 Envision Charlotte, *Envision Charlotte Annual Report 2012* (Charlotte, NC: Envision Charlotte, 2012), accessed July 2015, http://www.envisioncharlotte.com/wp-content/uploads/pdf/Annual-Report-2012.pdf.

86 Brad Turner, "*City of Atlanta Introduces Shine Program*," Atlanta Building News, April 2010, accessed July 2015, http://www.naylornetwork.com/gah-nwl/articles/abn.asp?aid=64603&projid=4172.

87 Southeast Energy Efficiency Alliance, *The Economic Impact of EE Investments in the Southeast* (Atlanta: Southeast Energy Efficiency Alliance, 2013), accessed July 2015, http://www.seealliance.org/wp-content/uploads/SEEA-EPS-EE-Report.pdf.

concluded that (1) developing at higher residential and employment densities would reduce vehicle miles traveled and (2) direct and indirect reductions in transportation energy use are possible through more compact, mixed-use development. Specifically, a doubling of metropolitan residential density combined with demand management measures could reduce household vehicle miles traveled by as much as 25 percent.[88] The Transportation Research Board also identified the ability of regional transportation organizations to incentivize more-compact developments and coupling development with transit.

88 Transportation Research Board, *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions* (Washington, D.C.: National Academies Press, 2009), accessed July 2015, http://www.nap.edu/catalog/12747/driving-and-the-built-environment-the-effects-of-compact-development.

CITY SUCCESS STORY

Atlanta Leverages Public-Private Partnerships

In November 2011 the City of Atlanta, Georgia, used a public-private partnership to launch the Atlanta Better Buildings Challenge (ABBC), an initiative to engage downtown businesses in reducing energy and water consumption in more than 40 million square feet of buildings by at least 20 percent by 2020, and a goal of becoming one of the country's 10 most sustainable cities. The Mayor's Office of Sustainability championed the initiative, which is aligned with Atlanta's sustainability plan, *Power to Change*, released in the fall of 2010. *Power to Change* lays out a plan for continuous improvement in sustainability practices through policies and activities that balance economic growth with environmental protection while being mindful of social justice.

Atlanta used a multi-pronged outreach approach to develop, establish, and market the ABBC. Atlanta convened meetings to develop the initiative, established a dedicated ABBC website, created marketing materials for interested participants, and designed public relations materials to inform the press and public about the initiative.

The City's primary partners in developing and implementing the ABBC were Central Atlanta Progress, a non-profit corporation of Atlanta business leaders; property owners; institutions committed to enhancing the environmental sustainability and economic vitality of Downtown Atlanta; and the Atlanta Downtown Improvement District, a public-private partnership funded through a community improvement district in which commercial property owners pay special assessments to support capital projects and programs.

Building owners and managers joined the ABBC by pledging to save energy and water in their selected buildings. Through the ABBC network of partners, participants were provided with tools and incentives such as guidance on making the case for energy upgrades, free building assessments, energy efficiency implementation technical assistance, education and training courses, access to project financing opportunities, and public recognition. The City is currently pursuing a performance contract to finance public building retrofit projects, and community participants will have access to financing options.

The City of Atlanta partnered with Georgia Power to streamline the sharing of energy data for energy consumed by participants in the Atlanta Better Buildings Challenge program. The city worked with its Department of Watershed Management to gain automatic access to data about facility-level water consumption. Atlanta also helped participants benchmark energy use in their buildings and provided software that automatically feeds energy use data into ENERGY STAR® Portfolio Manager, a no-cost web-based tool for tracking and reporting building energy use. Once collected, the aggregated participant energy and water data are displayed on a public-facing dashboard showing real-time progress against program milestones.

Since launching the challenge in 2011, Atlanta has been on track to meet its energy and water savings goals, and it continues to expand its goals by engaging additional private-sector partners to commit their buildings to energy improvements. In 2014, Atlanta buildings participating in the pilot saved 163 million gallons relative to their baseline consumption, enough water to fill 570 Olympic-sized swimming pools. One of the key benefits of this pilot program is being able to show participants the impact of their behavior based and infrastructure-based efforts.

The floor area of city buildings participating in the challenge increased from 40 million to 100 million square feet in four years. These facilities are reporting their energy data annually. And, they have collectively reduced their energy use intensity by 11 percent from a 2009 baseline and have improved their water performance by 20 percent from a 2010 baseline. Nearly a quarter of the 350 participating buildings have already achieved 20 percent savings. Annually, the city is using an average of 2.5 percent less energy and consuming 4 percent less water. Atlanta publicly recognized the program participants for their progress in achieving milestones and reaching goals through various marketing and public relations initiatives, including an annual recognition event supported by the city's mayor.

For more information, see www.atlantabbc.com.

Reference to a non-federal entity does not constitute an endorsement on the part of DOE or the U.S. government.

2.2 Business

American businesses can drive significant improvements to U.S. energy productivity, and they stand to benefit significantly from increasing energy productivity within their own operations. Although the importance of energy use may vary by type of business, improving energy productivity can be a universal source of enhancing competitiveness by increasing the amount of goods and services produced for a given amount of energy used. Strategies in this section were developed using feedback from the regional dialogues, the roundtable discussions, and goal endorsers. Notable contributions were provided by Raleigh regional dialogue participants for energy productivity in buildings and by St. Paul regional dialogue participants for advanced and smart manufacturing.

Lack of funding is a common barrier to reducing energy costs in businesses; the most significant financial barriers are insufficient internal capital budgets and competition with other capital investments.[89] To more clearly target recommended strategies, the *Roadmap* separates businesses into commercial (i.e., businesses that provide services and have lower energy intensities) and industrial groups (i.e., businesses that produce physical goods and have higher energy intensities). Both groups have the opportunity to encourage gains in energy productivity for their customers while offering them innovative products and services. Actions by businesses contribute to all six energy productivity wedges.

Smart Energy Systems
Technologies for Buildings Energy Productivity
Financing for Buildings Energy Productivity
Water Infrastructure
Smart Manufacturing
Transportation

2.2.1 COMMERCIAL BUSINESSES

2.2.1.1 New Financing Models

The investments needed across all sectors of the economy to increase energy productivity will require both existing and new innovations in financing mechanisms. Financing of investments is a barrier to increasing energy productivity for households, industrial businesses, and commercial businesses.[90] Together with strategies implemented by government

89 Johnson Controls, *Energy Efficiency Indicator: 2013 U.S. Results*, accessed July 2015, http://www.institutebe.com/InstituteBE/media/Library/Resources/Energy%20Efficiency%20Indicator/061213-IBE-Global-Forum-Booklet_I-FINAL.pdf.

90 Johnson Controls, *Energy Efficiency Indicator*: 2013 U.S. Results.

on the federal, state, and local levels, improved financing can facilitate the adoption of existing energy productivity technology and pave the way for new markets for yet-to-be commercialized technologies.

Small commercial buildings are an untapped source of energy productivity improvements, as is apparent in the potential investment value and energy savings for them; the investment value of the market for small building energy retrofits is estimated at $36.5 billion, with associated potential energy and utility bill savings of 420 trillion Btu and $138 billion, respectively.[91] The approaches required for tapping this potential differ from large enterprises and large commercial buildings, but public-private partnerships such as PACE financing and on-bill financing are examples of strategies to overcome the barriers for this market segment. As of January 2014, on-bill financing programs were operating or preparing to launch at least 25 U.S. states as well as in Canada and the United Kingdom. In aggregate, the 30 programs reviewed for a study done through SEE Action have delivered over $1.8 billion of financing to consumers for energy improvements.[92] Specific improvements for financing of small building energy efficiency projects include developing turnkey solutions, expanding contractor-led programs, and improving underwriting and program execution.[93]

2.2.1.2 Workforce Training

Increasing the energy efficiency of buildings is essential to meeting the energy productivity goal, yet building and construction contractors, and building trades professionals often lack awareness of the potential growth of the energy efficiency services sector, and more workers with energy efficiency qualifications are needed.[94] An instrumental strategy for overcoming this barrier is to incorporate energy efficiency into existing union and trade organization training programs, especially in ways that teach whole-building approaches to efficiency.[95] These organizations can also team with community and technical colleges, universities, and public utility commissions to effectively address the efficiency workforce education and training needs. For example, Pulaski Technical College in Arkansas offers energy efficiency courses for continuing education credits to professionals in the building trades.[96]

91 National Institute of Building Sciences Council on Finance, Insurance and Real Estate, *Financing Small Commercial Building Energy Performance Upgrades: Challenges and Opportunities* (Washington, D.C.: National Institute of Building Sciences, 2015), accessed July 2015, http://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/CC/CFIRE_CommBldgFinance-Final.pdf.

92 State and Local Energy Efficiency Action Network, *Financing Energy Improvements on Utility Bills: Market Updates and Key Program Design Considerations for Policymakers and Administrators* (Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, 2014), accessed July 2015, https://www4.eere.energy.gov/seeaction/system/files/documents/publications/executive/onbill_financing_es.pdf.

93 National Institute of Building Sciences, *Financing Small Commercial Building Energy Performance Upgrades: Challenges and Opportunities* (Washington, D.C.: National Institute of Building Sciences, 2014), accessed July 2015, http://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/CC/CFIRE_CommBldgFinance-Final.pdf.

94 Charles A. Goldman, Jane S. Peters, Nathaniel Albers, Elizabeth Stuart, and Merrian C. Fuller, *Energy Efficiency Services Sector: Workforce Education and Training Needs*, LBNL-3163E (Berkeley, CA: Lawrence Berkeley National Laboratory, 2010), accessed July 2015, http://emp.lbl.gov/publications/energy-efficiency-services-sector-workforce-education-and-training-needs.

95 Goldman et al. (2010).

96 "Continuing Education Credit Offerings," Pulaski Technical College, accessed July 2015, http://www.pulaskitech.edu/center_for_applied_building_sciences/continuing_education_credit_offerings.asp.

BUSINESS SUCCESS STORY

Lime Energy Tackles Barriers to Energy Efficiency in the Small and Mid-Sized Business (SMB) Segment

Lime Energy (Lime) is an energy services provider. One of its core strategies is to partner with utilities providing energy efficiency programs to small and mid-sized businesses (SMBs), a segment that represents the majority of commercial buildings in the United State. Since launching their innovative efficiency programs in 2011, Lime has delivered more than one billion kilowatt-hours of savings to over 100,000 SMBs, resulting in over $720 million of avoided energy costs while also adding 5,500 jobs to the U.S. economy. Lime Energy works directly for 12 of the top 25 utilities in the nation, having effectively brought energy savings performance contracting to their 1.4 million SMB customers.

Incentive programs targeting energy efficiency in commercial buildings have been implemented by utilities and program administrators for years, but they have struggled to gain participation from the SMB segment. These customers use nearly 50 percent of the energy consumed in the entire commercial building sector. Traditional barriers have included small business owners' lack of resources, their difficulty navigating technical energy efficiency concepts, and the high cost of acquiring these resources in the diverse SMB building sector. Lime Energy has spent the last four years attacking these problems head on. Below are examples of overcoming these barriers.

EXAMPLE: OVERCOMING THE SMB RESOURCE AVAILABILITY BARRIER

A south New York utility had run a commercial energy efficiency program for three years with little participation from customers with buildings under 10,000 square feet. The utility determined the low participation was because the program was too time-consuming and confusing for customers. Working with the utility, Lime Energy proposed an integrated program offering simplified customer participation. Lime installed a technology-driven delivery platform that enabled energy services representatives to take no more than 15 minutes to market the program, conduct an analysis, present financing options, and close the project. Given a small business owner's lack of availability, Lime's integrated approach and technology proved valuable to the utility, as it standardized and drastically shortened the time and customer involvement needed to initialize and implement the energy efficiency program.

EXAMPLE: OVERCOMING THE COST CONSTRAINT FOR SMBs

Utilities are often not adequately incentivized through state regulation to offer cost-effective energy efficiency programs to SMBs. One utility recognized the value of customer satisfaction and public goodwill that energy efficiency could bring to small businesses, but it needed help navigating tight budgetary constraints and a challenging policy landscape. Lime worked with the utility's program managers and with state policy advocates to design a program to fit this need. The program design was aimed at reducing energy efficiency program costs through technology and software innovation, increased staff effectiveness, marketing efficiency (through deep market segmentation and data analytics), and lowered project costs for consumers (through bulk procurement of efficiency measures with leading national distributors). Innovatively, Lime delivered these features to the utility in a guaranteed performance contract vehicle—similar to a power purchase agreement—easing concerns voiced by state regulators regarding runaway incentive budgets. This example shows how the "utility of the future" will deliver cost-effective, clean energy for their customers.

Through these tailored approaches, Lime Energy has directly financed over $9.2 million in efficiency projects, enabling 1,332 SMBs to participate in energy efficiency programs, and saving a collective 100,000 kWh in annual consumption in hard-to-reach markets such as restaurants, service stations, laundromats, and small retailers. Lime has influenced real customer behavior change, helping 1,747 small businesses make long-term investments of over $8.5 million in less than three years. Additionally, Lime's services increased customer satisfaction with utility energy efficiency programs to 96 percent, and overall satisfaction with the providing utility to 98 percent. Lime is helping utility clients move into the future, aligning their business goals with customer satisfaction while simultaneously reducing the emissions from the electricity they deliver. As regulations require increased delivery of energy efficiency resources, utilities have great potential in the SMB segment, for which Lime Energy's program delivery breakthroughs can be key. Lime's methods have made SMB energy efficiency delivery so cost effective that several utility clients are implementing these programs despite not having a regulatory requirement to do so.

For more information on Lime Energy's programs, their performance model, or the platform that powers it, see www.lime-energy.com.

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2.2.2 INDUSTRIAL BUSINESSES

Industrial businesses are critical participants in helping the United States meet the energy productivity goal because of their importance as energy users and engines of economic growth. These businesses also have the opportunity to provide new products and services that enable other businesses and sectors of the economy to improve their energy productivity. As a result, the industrial sector is well positioned to increase U.S. energy productivity through high-impact product innovation and the use of highly efficient manufacturing processes to streamline operations, improve productivity, and advance U.S. economic competitiveness.

In addition to increasing output using the same or less energy, energy productivity for industrial businesses can lead to substantial non-energy benefits or "co-benefits"[97] including reduced operations and maintenance costs, increased product quality, and improved worker health and safety. However, these co-benefits are often missing from the business case for projects that may increase a company's energy productivity. Getting funding for these projects may involve strategies such as having a separate capital account for proposed energy efficiency and energy productivity projects, or incorporating estimates of the value of energy productivity co-benefits.

The DOE's Better Plants Program (Better Plants) calls on its participants to demonstrate their commitment to increasing energy efficiency by voluntarily reducing their energy intensity by 25 percent over ten years. As of fall 2014, the 143 participants, representing nearly 11 percent of the total U.S. manufacturing footprint, reported cumulative savings of 320 trillion Btu and $1.7 billion in energy costs; this is enough energy to power the entire state of Vermont for over two years.[98] Building on the success of its participants, Better Plants started a pilot program to improve coordination of energy management practices between companies and their supply chains. For some manufacturers, much of the energy footprints of their products can be traced back to the materials and processes of their suppliers. Better Plants offers participating suppliers technical assistance, energy management training, and priority access to no-cost energy audits through DOE's IACs.[99] Johnson Controls, a Better Plants participant, achieved an annual energy intensity improvement of 8 percent,[100] and it is expanding its own supplier efficiency program by 60 suppliers by 2018. The company's program uses its own energy experts to train suppliers on identifying and implementing cost-effective energy efficiency investments. These efforts have helped suppliers achieve energy savings of 5-10 percent on investments with less than a two-year payback.[101]

97 International Energy Agency, *Capturing the Multiple Benefits of Energy Efficiency* (Paris: International Energy Agency, 2014).

98 U.S. Department of Energy Better Plants, "Progress Update: Fall 2014" DOE/EE-1140 (Washington, D.C.: U.S. Department of Energy, 2014), accessed July 2015, http://energy.gov/sites/prod/files/2014/09/f18/Better%20Plants%20Progress%20Update%202014.pdf.

99 U.S. Department of Energy Better Plants, "Overview: Supply Chain Pilot" (Washington, D.C.: U.S. Department of Energy, 2014), accessed July 2015, http://energy.gov/sites/prod/files/2014/07/f17/better_plants_supply_chain_pilot.pdf.

100 "Johnson Controls, Inc.," U.S. Department of Energy Better Buildings, accessed July 2015, http://betterbuildingssolutioncenter.energy.gov/energy-data/Johnson%20Controls,%20Inc.

101 Johnson Controls, Inc., "Johnson Controls teams up to scale energy efficiency in corporate supply chains," news release, June 11, 2015, http://www.prnewswire.com/news-releases/johnson-controls-teams-up-to-scale-energy-efficiency-in-corporate-supply-chains-300097486.html.

Small and medium enterprises that lack internal expertise in evaluating projects to increase energy productivity may find it beneficial to hire external assistance. Energy service companies can be a valuable partner in realizing reductions in energy use. They provide customers with guaranteed energy savings in return for payment from a portion of the achieved savings. Customers of energy service companies saved an estimated 33.7 terawatt-hours of electricity in 2012, equivalent to 2.5 percent of U.S. commercial electricity retail sales.[102]

2.2.2.1 Public-Private Partnerships

Partnerships between private business, government and universities for clean energy technologies are important enablers for meeting the energy productivity goal. Public-private partnerships can help increase access to capital, facilitate use of shared infrastructure, and lower technical risks. One notable example is the National Network of Manufacturing Innovation (NNMI), which focuses on R&D of foundational technologies that have potentially transformational technical and productivity impacts for the U.S. industrial sector. NNMI has established five institutes each of which focuses on a promising manufacturing approach or technology. For example, the institute Lightweight Innovations for Tomorrow (LIFT), which focuses on lightweight technology, has a project to reduce the wall thickness of ductile iron cast parts by 50 percent which could result in weight savings of 30–50 percent and associated energy efficiency benefits.[103] These institutes begin with federal support, but they are expected to operate with private-sector funding and without further federal funding after five years.

High-performance computing is another example where industry and public sector resources can join to increase energy productivity. Public-private partnerships in this space could further empower small and large businesses to harness the power of, as well as the modeling and simulation capabilities from, the national laboratory system—to improve R&D, reduce the time required to bring a product to market, and optimize production and supply processes.[104]

The Oak Ridge National Laboratory Manufacturing Demonstration Facility offers shared RD&D infrastructure for additive manufacturing and low-cost carbon fiber, which could be significant enablers of energy productivity, particularly in transportation applications and other technology areas.[105] The facility provides industries with the types of technical expertise and state-of-the-art technology that reduce risk and accelerate the commercialization of innovative new processes and products.

102 Juan Pablo Carvallo, Peter H. Larsen, and Charles A. Goldman, *Estimating customer electricity savings from projects installed by the U.S. ESCO industry*, LBNL-6877E (Berkeley, CA: Lawrence Berkeley National Laboratory, 2014), accessed July 2015, http://emp.lbl.gov/sites/all/files/lbnl-6877e.pdf.

103 Lightweight Innovations for Tomorrow, "LIFT Announces First Technology Project will Focus on Iron Alloys in Thin-Wall Castings," news release, July 16, 2015, http://lift.technology/lift-announces-first-technology-project-will-focus-on-iron-alloys-in-thin-wall-castings/.

104 Council on Competitiveness, *Strengthen: Dialogue 5* (Washington, D.C.: Council on Competitiveness, 2015), accessed July 2015, http://www.compete.org/storage/documents/CoC_AEMC_D5_Strengthen_FINALv2.pdf.

105 Oak Ridge National Laboratory, *Manufacturing Demonstration Facility*, ORNL 2013-G00529/aas (Oak Ridge, TN: Oak Ridge National Laboratory, 2013), accessed July 2015, http://web.ornl.gov/sci/manufacturing/docs/MDF-factSheet.pdf.

SMALL BUSINESS SUCCESS STORIES

Eck Industries, South Shore Millwork, and Mid-South Metallurgical

Eck Industries of Manitowoc, Wisconsin, is a small four-generation, family-owned aluminum foundry. Eck Industries took advantage of the resources made available through Wisconsin's Focus on Energy program, an initiative that provides technical and financial resources for energy efficiency projects. Eck Industries worked with the state program to implement a lighting retrofit project that would better illuminate its production facilities. The lighting efficiency improvements proved successful—the new energy-efficient bulbs reduced the energy intensity of the facility's lighting by 46 percent, the project paid for itself in approximately eight months, and the company realized annual operating savings of more than $55,500.[1]

South Shore Millwork is a small business providing fine architectural woodwork in Norton, Massachusetts. In an effort to improve the efficiency of their millwork shop, the company reached out to Mass Save, an energy efficiency initiative sponsored by Massachusetts utility and efficiency companies. Through the program, South Shore Millwork installed high-efficiency lighting systems and controls, occupancy sensors, and variable speed drives at a total project cost of $218,000. The project saved $30,500 annually (a payback period of 4.5 years), and it reduced carbon emissions reduction by more than two tons annually.[2]

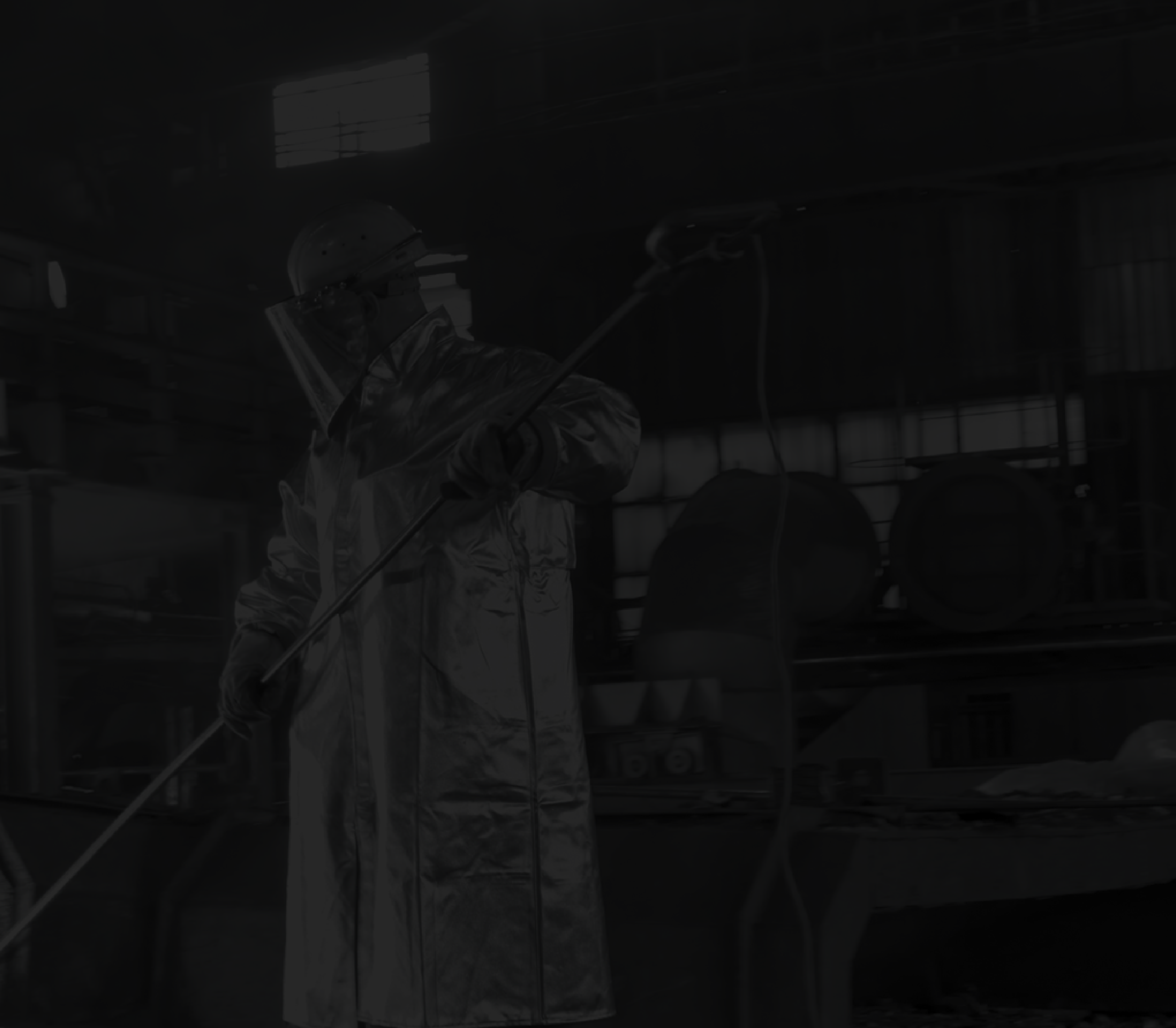
Mid-South Metallurgical is a niche commercial heat-treating company in Murfreesboro, Tennessee. The Mid-South Metallurgical facility operates 24 hours a day and it must accommodate furnace temperatures ranging from 120°F to 2375°F. To address efficiency challenges, the Industrial Assessment Center sponsored by the DOE at the University of Tennessee conducted an evaluation in which they discovered several areas where the company could save energy, including through better furnace insulation. Also found were opportunities to lower peak energy demand through an electrical demand system, energy-efficient furnace burner tubes, and improvements in the lighting system. By adopting these

1 http://www.energy.gov/sites/prod/files/2014/05/f16/eck_industries_case_study.pdf

2 http://www.masssave.com/~/media/Files/Business/Case-Study/EE5200_MassSave_SouthShore.pdf

recommendations, Mid-South Metallurgical lowered its energy use by 22 percent and decreased its energy costs by 18 percent, helping the company remain competitive through the recession and earning DOE's Energy Champion Award.[3]

Reference to a non-federal entity does not constitute an endorsement on the part of DOE or the U.S. government.



3 http://www.energy.gov/sites/prod/files/2014/05/f16/midsouth_metallurgical_casestudy.pdf

2.2.2.2 Energy Management System Certification

Establishing and certifying an energy management system that systematically tracks, measures, and continually improves energy performance can serve as the foundation for increasing the energy productivity of industrial businesses. For example, manufacturers may focus on the energy used in their processes, as 18 percent of the manufacturing sector's total electricity use is due to direct non-process uses such as facility lighting and space conditioning.[106] Participation in DOE's Superior Energy Performance program, which includes achieving certification under the International Organization for Standardization (ISO) 50001 standard and the American National Standards Institute (ANSI)/MS Standard 50021, yielded average energy savings of $500,000 per year, which is equivalent to a two-year payback period.[107] Additionally, program participants have noted that certification provided more awareness of and confidence in energy performance improvements, unlocking additional resources to fund further improvements.

2.2.2.3 Advanced Manufacturing

Advanced manufacturing is composed of "efficient, productive, highly integrated, tightly controlled processes across a spectrum of globally competitive U.S. manufacturers and suppliers."[108] Reinvigorating the U.S. industrial sector by fostering the growth of advanced manufacturing capabilities will also provide high-quality jobs, which can further improve the U.S. economy. However, in order to bring about the changes necessary for advanced manufacturing, private investment needs to be complemented by public investment.[109]

Information and communications technology (ICT), including sensors and controls that enable optimized energy consumption in plants and other buildings, can be important for enabling energy productivity gains for companies. These ICT-rich systems are also integral to improving product quality and communication technology that is now being deployed in the electric power sector, where it is often called the smart grid, where it is enabling better use of labor, materials, and capital inputs more efficiently, productively and cleanly, thus supporting economic efficiency and some forms of energy productivity improvements. Estimates of the market size for these technologies range from $43 billion in potential sales

106 "2010 MECS Survey Data," U.S. Energy Information Administration, accessed July 2015, http://www.eia.gov/consumption/manufacturing/data/2010/.

107 Peter Therkelsen, Ridah Sabouni, Aimee McKane, and Paul Scheihing, "Assessing the Costs and Benefits of the Superior Energy Performance Program" (paper presented at the ACEEE Summer Study on Energy Efficiency in Industry, Niagara Falls, NY, 2013), accessed July 2015, http://energy.gov/sites/prod/files/2014/07/f17/sep_costbenefits_paper13.pdf.

108 "Made in America: The Next-Generation of Innovation," National Institute of Standards and Technology Advanced Manufacturing National Program Office, accessed July 2015, http://www.manufacturing.gov/advanced_manufacturing.html.

109 President's Council of Advisors on Science and Technology, Report to the President on Ensuring American Leadership in Advanced Manufacturing (Washington, D.C.: The White House, 2011), accessed July 2015, https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-advanced-manufacturing-june2011.pdf.

for building automation technologies by 2018[110] to over $120 billion for manufacturing automation sales by 2020.[111] While acknowledging cyber security concerns, attendees at the *Roadmap* regional dialogues noted the value of a standard protocol for new ICT products to allow interoperability between new entrants in this market. This QER also identified this.[112] The next section discusses strategies to develop new business models around enabling customers' energy productivity.

2.2.2.4 Innovative Products to Enable Energy Savings

The most significant opportunity for industry to help the U.S. meet its energy productivity goal is to develop, manufacture, and sell products and services that enable energy productivity improvements for their customers. Developing new business models around enabling energy productivity improvements for customers requires a better understanding of where energy is used along a product's value chain or life cycle. Tools like life-cycle assessment allow companies to uncover and target which portion of their products' life-cycles use the most energy, as well as other resources like water. Depending on the product, the energy required by industry to produce a product may only be a small fraction of its total life-cycle energy.

Providing products (e.g., lighter weight materials) that reduce this energy use not only provide value to the customer, but also reduce overall energy use and potentially create new markets. Continued advances in solid state lighting technology (SSL), such as fully controllable color tuning, have resulted in new and growing applications for highly efficient lighting that are geared specifically for productivity improvements. A sampling of these applications include spectrally controlled lighting to make people more alert or to facilitate sleep; spectrally optimized lighting for crop growth and livestock rearing; and spectrally tuned lighting for visual inspection processes or other enhanced visibility functions.[113]

110 ABI, "Commercial Building Automation Market to Top $43 billion by 2018, Says ABI Research." Press Release, April 30, 2013. http://www.reuters.com/article/2013/04/30/ny-abi-research-idUSnBw306552a+100+BSW20130430. As cited in Rogers et al. Intelligent Efficiency: Opportunities, Barriers, and Solutions, Report number E13J (Washington, D.C.: American Council for an Energy-Efficient Economy, 2013), accessed July 2015, http://aceee.org/sites/default/files/publications/researchreports/e13j.pdf.

111 Cullien, Matt, Machine to Machine Technologies: Unlocking the Potential of a $1 Trillion Industry. The Carbon War Room (2013). As cited in Rogers et al. Intelligent Efficiency: Opportunities, Barriers, and Solutions, Report number E13J (Washington, D.C.: American Council for an Energy-Efficient Economy, 2013), accessed July 2015, http://aceee.org/sites/default/files/publications/researchreports/e13j.pdf.

112 U.S. Department of Energy, Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure.

113 Norman Bardsley, Stephen Bland, Lisa Pattison, Morgan Pattison, Kelsey Stober, Fred Walsh, and Mary Yamada, *Solid-State Lighting Research and Development Multi-Year Program Plan* (Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, 2014), accessed July 2015, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_mypp2014_web.pdf.

MANUFACTURING SUCCESS STORY

Legrand Employees Achieve 15.4 Percent Reduction over 26.2-Day "Energy Marathon"

Legrand is a manufacturing, global specialist in electrical and digital building infrastructures that effectively saved 588,540 kWh of electricity, enough energy to drive an electric car to the moon and back 3.3 times, in just 26.2 days during its "2014 Energy Marathon." These savings did not occur by chance, but rather through effectively leveraging previous efforts. First, Legrand became a Partner to the U.S. Department of Energy (DOE)'s Better Buildings, Better Plants Challenge, and committed to reducing its energy intensity by 20 percent from 2012 - 2022, on top of the 27 percent reduction the company achieved from 2009-2012. To tackle this new goal, Legrand conducted energy audits at manufacturing, warehouse, and office facilities, where the company identified energy efficiency opportunities with payback periods spanning immediate results to four years. Based on these audits, Legrand completed numerous technology upgrades and process changes across its facilities, and brainstormed new, innovative ways to engage its people.

In addition to DOE's resources, Legrand leveraged its own initiative, building on its "Power Down Day," a successful one-day energy efficiency event conducted in 2012, to create a 26.2-Day Energy Marathon. The Energy Marathon targeted longer-term energy behavior change, based on the idea that 'it takes 20 days to build a habit." Through the Energy Marathon individual sites established baseline electricity usage, and the site with the greatest percentage energy consumption reduction, compared to its baseline, was crowned the winner. A diverse steering committee and site leaders at each of the 18 participating locations drove energy savings at the facility level. For 26.2 days, site leaders read the facility's utility electric meter and reported the readings to a central event coordinator. Employees received daily tips for saving energy and event "standings" via emails, posters, and TV monitor displays – effectively driving competition through awareness and engagement.

As a result of employees' deliberate efforts to reduce energy consumption and some ready-to-implement technology changes at the facility level, the Energy Marathon reduced Legrand's electricity usage by

15.4 percent across the participating sites. In total, the company saved 588,540 kWh of electricity, preventing approximately 406 metric tons of CO_2 from entering the atmosphere. This amounted to a cost savings of $46,732 over the course of the 26.2-days. The winning facility achieved a 63.1 percent reduction vs. the baseline, while half of the participating sites exceeded a 20 percent reduction. Based on tracking data gathered since 2014, all sites are on goal to continuously reduce consumption based on Legrand's internal commitment and our Better Buildings, Better Plants Challenge pledge. Legrand has observed behavioral changes with more meetings and offices relying on natural light rather than overhead lighting. Part of the lasting impact is the awareness more of our employees have of our commitment to reduce our energy consumption. Since the majority of energy savings could be attributed to behavioral change and education, savings are expected to continue into the future in concurrence with repeating the competition and continuing energy education.

Looking beyond the event's tangible energy and cost savings, Legrand was able to bolster the visibility of its overall sustainability initiatives and highlight the importance of energy efficiency – both in terms of competiveness as a company and to the environment. The competition made saving energy fun and engaging for employees – something that will leave a lasting imprint on future sustainability events and campaigns. Legrand shares its experience in tools available for free download on its sustainability webpage.

A step-by-step guide to conducting your own Energy Marathon as well as other tools to help others save energy can be found at: http://www.legrand.us/aboutus/sustainability/high-performance-buildings/tools-and-downloads.

Reference to a non-federal entity does not constitute an endorsement on the part of DOE or the U.S. government.

2.3 Electric Utilities

Utilities—including investor-owned utilities, municipalities, and cooperatives—have significant potential to impact energy productivity through increased investments and reduced Btu consumption. In 2013, ratepayer-funded energy efficiency programs saved an estimated 23.16 billion kWh of electricity or 0.6 percent of U.S. retail electricity sales in 2013.[114] Such programs show the potential to increase energy productivity through reducing energy consumption. Although these energy efficiency impacts are important for increasing energy productivity, potentially even larger impacts could result from cost-effective investments. Investing in upgraded infrastructure and technologies, along with potential revenue increases from new product and services would induce economic growth. Through market transformation programs and other innovations, the electricity sector serves as a leader and test bed for enabling new technologies with products, services, and markets that contribute to energy productivity improvements. This section of the *Roadmap* takes a holistic look at the energy system and focuses on enhancing U.S. energy productivity through accelerated efforts to implement a smarter, modernized electric energy system.

Together with utilities, public utility commissions and public service commissions[115] can be drivers of electricity rate designs, distributed generation deployment, energy efficiency programs, and other strategies that increase energy productivity. For example, moving from traditional block electricity pricing to time-variant rates can be critical for the functioning of a smarter grid, integration of distributed energy resources (DER) like wind and solar, and adjusting to slower growth in electricity use. Actions by electric utilities contribute to all six energy productivity wedges:

Smart Energy Systems
Technologies for Buildings Energy Productivity
Financing for Buildings Energy Productivity
Water Infrastructure
Smart Manufacturing
Transportation

2.3.1 GRID INFRASTRUCTURE ENERGY PRODUCTIVITY

The term "smart grid" refers to modernization of the electricity delivery system through the deployment of information and communication technologies that can enable greater consumer interaction and choice, as well as monitor, protect,

114 Consortium for Energy Efficiency, *2014 State of the Efficiency Program Industry: Budgets, Expenditures, and Impacts* (Boston: Consortium for Energy Efficiency, 2015), accessed July 2015, http://library.cee1.org/sites/default/files/library/12193/CEE_2014_Annual_Industry_Report.pdf.

115 The name utility regulatory entities vary by state. The most common names are "public utility commission" and "public service commission."

and automatically optimize the operation of its interconnected elements. Smart grid applications offer great potential to increase the economic efficiency, and at times the energy efficiency, of U.S. power generation, transmission, and distribution while creating a more versatile, resilient, and reliable electric power grid.

Elements of the smart grid can allow for energy productivity benefits by enabling more energy efficiency in a number of areas, such as either at the end use or in the transmission and distribution of energy; reduced energy losses in the transmission and distribution system; and the ability to enable end-users more choice in their electricity consumption-resulting in reduced electricity use instead of new generation. For example, use of smart meters allows for the elimination of transportation energy used for manual meter reading as well as less transportation energy used for utility repair crews due to more precise detection and understanding of local electricity outage.

The smart grid enables more rapid adoption of distributed power generation and storage as well as the increased use of electric vehicles to become available to consumers more readily and easily available to consumers, without barriers or restrictions. Smart grid technologies also permit utilities to more actively manage voltage levels along their distribution circuits; when voltage levels can be optimized and reduced through conservation voltage practices, a considerable amount of energy savings can be realized without compromising reliability. Without the development of the smart grid, the full value of many individual technologies like electric vehicles, automated household devices, demand response, distributed resources such as residential solar, and larger-industrial distributed generation might not be fully realized.

Multiple regional dialogue participants at Accelerate Energy Productivity 2030 dialogues emphasized the transformative potential of a standard protocol for data to be communicated between smart grid devices. In the QER, the Administration recommended that DOE work with industry, the Institute of Electrical and Electronics Engineers, state officials, and other interested parties to identify additional efforts the Federal Government can take to better promote open standards that enhance connectivity and interoperability on the electric grid.[116] DOE efforts to support the development of voluntary standards in a number of areas continue.[117] These standards will allow devices created and operated by different companies to communicate, contributing to interoperability between grid technologies and increasing the value of smart grid technologies for all consumers. Standards are also important for the adoption of smart manufacturing, as described previously in the section on advanced manufacturing.

2.3.1.1 Reducing Economic Losses from Power Outages

Studies conducted by the Electric Power Research Institute (EPRI) show the annual cost of power disturbances to the

116 U.S. Department of Energy, *Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure.*

117 "Smart Buildings Equipment Initiative," U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, accessed July 2015, http://energy.gov/eere/buildings/downloads/smart-buildings-equipment-initiative.

U.S. economy ranges between $119 and $188 billion per year.[118] The societal cost of a massive blackout is estimated to be in the order of approximately $10 billion per event.[119]

Smart grid technologies and infrastructure, such as automated feeder switches and smart meters, offer utilities the potential to provide more reliable energy, particularly during challenging emergency conditions, while managing their costs more effectively through real-time metrics with the smart grid. These benefits that reduce costs for utilities create spillover benefits of lower electricity prices, or of no price increases, to customers. Lower costs and decreased infrastructure requirements in turn enhance energy productivity, and reduced costs increase economic activity, which benefits society.

2.3.1.2 Effects of a Flexible Smart Grid on Energy Productivity

Transitioning the country's electric energy system to a smarter, modern system could result in direct energy productivity benefits through enhanced infrastructure investments, and more significantly, indirect benefits through enabling two-way flow of electricity and information. Managing the flow of information and electricity in two directions (traditionally electricity flows in one direction from large power generation stations through transmission and distribution grids to consumers) will enable the effective integration of electric vehicles, smart buildings and houses, distributed generation systems (such as rooftop solar systems), and energy storage devices with the electric grid and open opportunities for new markets where participants are rewarded for providing enhancements in efficiency and resiliency. The total economic value generated from a fully deployed smart grid is estimated as high as $130 billion annually.[120]

2.3.1.3 Improving Electric Generating Unit Heat Rates to Gain Energy Productivity

Results of a recent analysis indicate that approximately 4.6 percent of electricity is consumed in the production of electricity itself, making the electric sector the second largest electricity consuming industry in the United States.[121] The performance of a thermoelectric power plant can be measured by its heat rate—the efficiency of conversion from fuel energy input to electrical energy output. A generating unit with a lower heat rate can generate the same quantity of electricity than a unit with a higher heat rate while consuming less fuel to generate electricity. Lower fuel use per unit of electricity generated also reduces the corresponding emissions of pollutants.

118 David Lineweber and Shawn McNulty, *The Cost of Power Disturbances to Industrial & Digital Economy Companies* (Palo Alto, CA: Electric Power Research Institute, 2001), accessed July 2015, http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002000476.

119 119 U.S.-Canada Power System Outage Task Force, *Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations* (Washington, D.C.: U.S. Department of Energy, 2004), accessed July 2015, http://energy.gov/oe/downloads/blackout-2003-blackout-final-implementation-report.

120 Booth, Adrian, Mike Green, Humayun Tai, *U.S. Smart Grid Value at Stake: The $130 Billion Question* (McKinsey, 2010), accessed July 2015, http://www.mckinsey.com/~/media/McKinsey/dotcom/client_service/EPNG/PDFs/McK%20on%20smart%20grids/MoSG_130billionQuestion_VF.ashx.

121 C. Gellings, *Program on Technology Innovation: Electricity Use in the Electric Sector* (Palo Alto, CA: Electric Power Research Institute, 2001), accessed July 2015, http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001024651.

Modern coal-fueled power plants now achieve net conversion efficiencies of over 39 percent.[122] A variety of technologies show potential to increase efficiency of power plants. Examples include: the incorporation of adjustable-speed-drive mechanisms for plant motors; turbine upgrades for higher temperatures and pressures; advanced materials for expanded operational temperature ranges; condenser upgrades; replacement seals and firing system upgrades and diagnostics; and sensors and controls for optimizing performance.[123]

Over 80 percent of the U.S. electric power generation capacity comes from thermal turbines.[124] Consequently, improving heat rates at existing generators can lower fuel costs and help achieve compliance with environmental regulations. A heat rate improvement of 1 percent on a single 500-megawatt (MW) base-loaded coal-fired unit can save $700,000 per year in fuel costs alone, and it can reduce carbon dioxide (CO2) emissions by approximately 40,000 tons per year.[125]

2.3.1.4 Using Utilities to Improve Energy Productivity by Delivering End-Use Energy Efficiency

Utilities started delivering energy efficiency services in the 1980s, many of which are now standard, with regulators adopting policies to encourage and mandate them. Demand side energy efficiency driven by the 2015 Clean Power Plan is expected result in a 7 percent reduction in electricity demand by 2030.[126] A utility faces the following financial concerns adopting an energy efficiency program:

- Failure to recover program costs in a timely way has a direct impact on utility earnings.
- Reductions in sales due to energy efficiency can reduce utility financial margins.
- As a substitute for new supply-side resources, energy efficiency reduces the earnings that a utility would otherwise earn on the supply resource.[127]

122 The Coal Utilization Research Council and the Electric Power Research Institute, *The CURC-EPRI, Advanced Coal Technology Roadmap* (Washington, D.C.: Coal Utilization Research Council, 2015), accessed July 2015, http://www.coal.org/#!curc-epri-roadmap/c1r5g.

123 "Sources of Greenhouse Gas Emissions: Electricity Sector Emissions," U.S. Environmental Protection Agency, last modified May 7, 2015, http://www.epa.gov/climatechange/ghgemissions/sources/electricity.html; U.S. Environmental Protection Agency Sector Policies and Programs Division, *Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Coal-Fired Electric Generating Units* (Research Triangle Park, NC: U.S. Environmental Protection Agency, 2010), accessed July 2015, http://www.epa.gov/nsr/ghgdocs/electricgeneration.pdf; Eric Grol, Thomas J. Tarka, Steve Herron, Paul Myles, and Joseph Saracen, *Options for Improving the Efficiency of Existing Coal-Fired Power Plants*, NETL-2013/1611 (Pittsburgh: National Energy Technology Laboratory, 2014), accessed July 2015, http://www.netl.doe.gov/File%20Library/Research/Energy%20Analysis/Publications/Efficiency-Upgrade-Final-Report.pdf.

124 U.S. Energy Information Administration, *Electric Power Annual 2007*, EIA-0348(2007) (Washington, D.C.: U.S. Department of Energy, 2009), accessed July 2015, http://www.eia.gov/electricity/annual/archive/03482007.pdf.

125 S. Korellis, Range and Applicability of Heat Rate Improvements (Palo Alto, CA: Electric Power Research Institute, 2014), accessed July 2015, http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003457&Mode=download.

126 "Fact Sheet: Energy Efficiency in the Clean Power Plan", United States Environmental Protection Agency, last updated August 20, 2015, http://www2.epa.gov/cleanpowerplan/fact-sheet-energy-efficiency-clean-power-plan.

127 National Action Plan for Energy Efficiency, *Aligning Utility Incentives with Investment in Energy Efficiency* (Washington, D.C.: U.S. Environmental Protection Agency, 2007), 2-1, accessed July 2015, http://www.epa.gov/cleanenergy/documents/suca/incentives.pdf.

These financial concerns can be effectively addressed through mechanisms such as decoupling and lost revenue adjustment mechanisms. These concerns are part of the broader discussion of evolving utility business models. The QER noted the impact and implications of new technologies, including those that facilitate increased energy productivity, including end-use efficiency on particularly the distribution part of utilities: "At high penetrations, many of these new technologies could challenge current distribution systems and the functional integrity of the current electricity system. New investments and changes to existing regulatory, policy, financial, and business structures may be necessary to fully realize the benefits of these technologies. Regulators and policymakers will need to address the operational issues associated with new technologies, as well as longer-term concerns, such as how the loss of revenue (and a utility's ability to cover fixed costs) and load resulting from increasing numbers of installations could challenge utilities' financial health under current business models."[128]

2.3.2 PROMOTING ENERGY PRODUCTIVITY IN RATE DESIGN

Since the year 2000, as noted in the QER, "many states have adopted policies to support utility investments in energy efficiency."[129] There are at least three different regulatory approaches being used: decoupling, lost revenue adjustment mechanism, and a broad set of methods to allow performance incentives. These efforts create a regulatory model that rewards utility shareholders for effective energy efficiency efforts that lower ratepayer bills in the long term. These three general categories of regulatory policy and rate-setting changes serve to address negative financial effects on utilities. Thus, they do modify the distribution utility's business model by making it at least neutral and in some cases, providing a financial return, for delivering energy efficiency to their customers, which represents a prime method of improving energy productivity.

The last decade and a half shows substantial growth in utility-delivered energy efficiency, whether through state's adopting mandates known as energy efficiency portfolio standards or allowing changes to distribution utility business models through the three regulatory policy and rate-setting categories noted earlier. Utility-delivered energy efficiency is projected to grow aggressively over the next decade through a combination of all these measures. The QER found that, "Appropriate valuation of new services and technologies and energy efficiency can provide options for the utility business model," but that "Different business models and utility structures rule out 'one-size-fits-all' solutions to challenges."[130]

While no single approach will be effective in meeting the needs of electricity customers in every part of the United States, information about the economic value of new grid services can provide clear signals to the range of entities that

128 U.S. Department of Energy, *Quadrennial Energy Review: Energy Transmission, Storage*, and Distribution Infrastructure, 3-17.

129 U.S. Department of Energy, *Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure*, 3-20.

130 U.S. Department of Energy, *Transforming U.S. Energy Infrastructures in a Time of Rapid Change: The First Installment of the Quadrennial Energy Review, Summary for Policymakers* (Washington, D.C.: U.S. Department of Energy, 2015), S-15, accessed July 2015, http://energy.gov/epsa/downloads/quadrennial-energy-review-full-report.

finance, plan, and operate the grid. Policies to provide consumers with affordable and reliable electricity must take into account the variety of business models for investing, owning, and operating electric grid infrastructure. Doing so could allow actors to make investments that deliver electric services at lowest cost. As new technologies develop, electric markets regulated by a patchwork of state and local jurisdictions may be hard-pressed to perform timely cost-benefit analysis to determine the value of new offerings to their ratepayers.

The federal government can use its convening power to gather information from a broad range of stakeholders, and it can provide tools and resources for understanding the value of services provided by new and innovative technologies. Such resources would allow policymakers to make informed decisions about how best to leverage new technologies in their communities to support growing energy productivity.[131] For example, Michigan passed the Clean, Renewable, and Efficient Energy Act in 2008. This act allowed certain utilities to decouple their rates thus making the utilities financially neutral to negative financials resulting from increased ratepayer energy efficiency; the act also required electric and natural gas utilities to help consumers increase the energy efficiency of their homes and businesses. These programs are expected to result in over $700 million in value to customers, and in 2011, the program achieved enough savings to power 1.5 million homes and heat 40,000 homes for a year.[132]

More sophisticated rate structures have the potential to (1) unleash additional new investments and innovations in distributed energy resources and (2) direct the deployment of these resources in a manner that maximizes the benefits to the system as a whole. With advanced rate structures, utility earnings could depend more on creating value for customers and achieving policy objectives. Freed from the business model that made new infrastructure a precondition for new profits, utilities could find earning opportunities in enhanced performance and in transactional revenues. With utilities focused on delivering value to customers, and not just on energy, productivity could be increased even while ratepayers consume less energy.

131 U.S. Department of Energy, *Transforming U.S. Energy Infrastructures in a Time of Rapid Change: The First Installment of the Quadrennial Energy Review, Summary for Policymakers.*

132 John D. Quackenbush, Greg R. White, and Sally A. Talberg, Report on the *Implementation of P.A. 295 Utility Energy Optimization Programs* (Lansing: Michigan Public Service Commission, 2015), accessed July 2015, http://www.michigan.gov/documents/mpsc/PA_295_Renewable_Energy_481423_7.pdf. Sept. 2013.

UTILITY SUCCESS STORY

Gulf Power's "Energy Select" Program Places Energy Efficiency in Consumers' Hands

Gulf Power, a subsidiary of Southern Company, is an investor-owned electric utility that serves more than 435,000 residential customers in northwest Florida. As are many investor-owned utilities, electric utilities are often mandated by local, state, and federal regulators to increase efficiency and sustainability measures while continuing to meet ever-increasing demand for power. Demand-side management programs, in the form of a reliably controlled demand reduction during critical-peak periods, have become a popular tool to meet these demands. However, the challenge for utilities with this type of demand-side management program is to obtain the amount of load control and verification they require while sufficiently incentivizing customers to participate.

As early as 1989, Gulf Power began to develop this solution to meet this challenge with the help of the Florida Public Service Commission. After years of development, Gulf Power officially launched Energy Select in 2000 as part of its broader EarthCents program and quickly gained attention as the first utility to provide a fully automated critical peak pricing program in the United States.

Energy Select is a demand-side management program that employs price-responsive programmable thermostats and timers for water heater and pool pumps. And, it uses a "residential service variable pricing" rate that features four different prices based on the time of day, the day of week, and the season that reflect the actual cost of producing electricity during those periods. With this program, Gulf Power found a way to combine dynamic pricing with a consumer-controlled management system to incentivize behavioral change in customers that avoids using excess electricity based on daily schedules, comfort levels, or market patterns—effectively reducing peak load levels and enabling reliable electric service.

On average, the program helps over 15,000 customers save up to 15 percent annually on electricity purchases. The benefits of Energy Select have also translated to a boost in overall customer satisfaction with the electric utility service itself, resulting in customer satisfaction rates as high as 95 percent and allowing program participants to take advantage of lower electricity prices 87 percent of the time.

Reference to a non-federal entity does not constitute an endorsement on the part of DOE or the U.S. government.

For more information, see www.gulfpower.com/residential/earthcents/energy-select/.

2.4 Water Utilities

In a 2002 report, EPRI estimated that 4 percent of the nation's electricity use goes towards moving and treating water and wastewater.[133] Providing the same water services while consuming significantly less energy offers a significant contribution to meeting the productivity goal. Actions taken by public and private water utilities contribute to two energy productivity wedges:

Smart Energy Systems
Water Infrastructure

Energy consumption by public drinking water and wastewater utilities represents a substantial cost for both public and private water systems. The cost of energy for municipal water systems can be extraordinarily burdensome for localities, accounting for as much as 25-40 percent of their energy bills.[134] Local governments can reduce energy use at water and wastewater facilities through energy efficiency programs, waste to energy technologies, measures that promote water conservation, investments that prevent water loss and reduce storm water.[135] For example, the Missouri Water Utilities Partnership, a public-private partnership, identified and implemented strategies projected to reduce water-related electricity use by more than 8 million kWh per year, which is enough energy to power over 730 homes for a year.[136]

Infrastructure is also pivotal to ensuring water and energy savings. Nationwide, aging, leaking infrastructure results in significant energy waste, with national estimates of leaks and other losses as high as 20-25 percent.[137] This indirectly translates to energy waste from additional required treatment and pumping. The situation can be addressed through advanced leak monitoring, advanced pressure management, and accelerated replacement of buried infrastructure.

133 R. Goldstein and W. Smith, *Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment—The Next Half Century* (Palo Alto, CA: Electric Power Research Institute, 2002), accessed July 2015, http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001006787.

134 Malcolm Pirne, *Statewide Assessment of Energy Use by the Municipal Water and Wastewater Sector* (Albany: New York State Energy Research and Development Authority, 2008).

135 Design features that reduce stormwater include permeable pavements, green roofs, and rain gardens. See "Stormwater Management Best Practices," U.S. Environmental Protection Agency, last modified November 5, 2012, http://www.epa.gov/oaintrnt/stormwater/best_practices.htm.

136 U.S. Environmental Protection Agency, *Energy Efficiency in Water and Wastewater Facilities: A Guide to Developing and Implementing Greenhouse Gas Reduction Programs* (Washington, D.C.: U.S. Environmental Protection Agency, 2013), accessed July 2015, http://www.epa.gov/statelocalclimate/documents/pdf/wastewater-guide.pdf.

137 Black & Veatch, "Buried Infrastructure", accessed July 2015, http://bv.com/reports/2013/2013-water-utility-report/buried-infrastructure; Ashley Halsey III, "Billions needed to upgrade America's leaky water infrastructure," Washington Post, January 2, 2012, http://www.washingtonpost.com/local/billions-needed-to-upgrade-americas-leaky-water-infrastructure/2011/12/22/gIQAdsE0WP_story.html.

At drinking water plants, the largest energy use (about 80 percent) is to operate motors for pumping.[138] There is a recognized potential to improve the efficiency of water utility pumping processes by as much as 30 percent.[139] Water utilities like American Water are implementing pump efficiency programs. Improving the efficiency of motors used in water pumps from the current average of 55 percent to 80 percent would save 10 million MWh per year, the equivalent of lighting a city the size of Chicago for over two years.[140]

There is also significant opportunity for improving the wastewater aeration process, which consumes 30-50 percent of all energy in wastewater treatment plants. This can be accomplished through the use of more efficient aeration or the use of anaerobic processes that do not require aeration. Nutrient removal is also energy-intensive. Thus, more efficient microbial processes to remove nitrogen and phosphorus from wastewater, can also significantly reduce energy consumption.[141]

Waste streams from wastewater treatment plants provide a valuable energy source that can displace primary energy consumption. There is enough embedded energy in the waste streams of many wastewater treatment plants to achieve net zero or even net positive energy consumption. For example, many plants are currently using methane digesters with CHP to produce biogas and/or electricity from their waste streams and reduce the amount of electricity they draw from the grid.

Beyond improving the efficiency with which utilities move and treat water, energy savings can be realized by more efficient end-use of water. Indeed, "water-related energy consumption was 12.6 percent of national primary energy consumption in 2010."[142] Reducing this end user water consumption can thus have an indirect and significant impact on energy consumption. Outdoor watering practices can also indirectly waste energy. Technologies such as drip irrigation and low-flow plumbing fixtures can improve water use efficiency, which indirectly translates into energy savings.

2.4.1 RATE REFORM

Water utilities have the same financial conundrum as energy utilities do when it comes to incenting water and energy efficiency. Concerns over cost recovery and losses of sales limit the financial viability of energy and water efficiency programs. Under most rate structures, there are no water efficiency incentives, as recovery of fixed costs is dependent

138 Claudia Copeland, Energy-Water Nexus: The Water Sector's Energy Use (Washington, D.C.: U.S. Congressional Research Service, 2014), accessed August 2015, http://fas.org/sgp/crs/misc/R43200.pdf.

139 EPRI and WRF, Electricity Use and Management in the Municipal Water Supply and Wastewater Industries, 2013.

140 American Water, *The Water-Energy Nexus: EPA's Clean Power Plan* (Voorhees, NJ: American Water, 2014), accessed July 2015, http://www.amwater.com/files/WaterEnergy%20EPA%20Clean%20Power%20Plan%20v2.pdf.

141 U.S. Department of Energy, The Water-Energy Nexus: Challenges and Opportunities (Washington, D.C.: U.S. Department of Energy, 2015), accessed August 2015, http://www.energy.gov/sites/prod/files/2014/07/f17/Water%20Energy%20Nexus%20Full%20Report%20July%202014.pdf.

142 Claudia Copeland, Energy-Water Nexus: The Water Sector's Energy Use (Washington, D.C.: U.S. Congressional Research Service, 2014), accessed August 2015, http://fas.org/sgp/crs/misc/R43200.pdf.

on volume of water sold. This clashes with an ever-increasing need to be more resource efficient given the realities of water scarcity, stressed water systems and droughts, as well as rising energy costs.

Decoupling, and other investment recovery reforms, is vital to ensuring that water and wastewater utilities have the incentives and the tools to reduce water and energy consumption. By separating volumes of water sold, from rates charged, decoupling enables water companies to help customers use less water and therefore save more energy. Likewise, investment recovery reform can help accelerate the replacement of aging leaking water mains, thus reducing energy waste. These regulatory reforms will ultimately minimize energy costs and reduce carbon emissions related to water and wastewater services.

WATER UTILITY PUMP EFFICIENCY ENERGY SAVINGS SUCCESS STORY

American Water

Much of American Water's energy efficiency work concentrates on improving pump efficiencies through refurbishment and/or replacement. A total of 52 pump refurbishments/replacements were completed from 2011-2013, at a cost of approximately $6 million, and provided an estimated energy reduction of 8 million kWh/year.

American Water manages its energy program using an Energy Usage Index (EUI) metric derived by dividing total power usage in megawatt-hours (MWh) by the volume of water sold in million gallons (MG) during a discrete period of time. The current baseline for this metric is 2.89 based on 2011-2013 operating data. The EUI data is collected and monitored to serve as a barometer for the condition of the pump fleet. Specifically, as pumps age, they wear and become less hydraulically efficient, which translates to more power required to deliver the same volume of water. American Water's pumping inventory is comprised of about 7,500 centrifugal pumping units. Of this, it is estimated that about 20 percent of the largest pumps consume 80 percent of American Water's total power usage.

American Water also conducts wire-to-water efficiency testing to monitor the efficiency of pumps and motors. We deliver over a billion gallons of water each day, so even a small increase in efficiency can yield energy savings. Research has shown that the average "wire-to-water" efficiency of existing "in-field" water utility pumps is about 60 percent. New installations are designed to achieve efficiencies of between 76 percent and 82 percent. American Water sees this as a major opportunity to decrease its carbon footprint. By replacing or refurbishing older pumps, studies have shown that pump efficiencies can be restored to their original efficiencies of 76-82 percent. This efficiency gain may yield energy savings of 10-20 percent at facilities that have completed pump improvements.

American Water pump refurbishment programs maintain, repair and replace pumps, motors and variable frequency drive (VFD) equipment. The cost of pump replacement/ refurbishment to recover capacity and improve efficiency is weighed against the typical decline in efficiency/capacity over time. American Water has vibration analysts on staff to extend pump service life through predictive maintenance.

For more information, see: http://files.shareholder.com/downloads/AMERPR/599810257x0x530218/15116DF7-78E3-45BA-BB9C-6101BD705B70/WP_Innovations_in_Energy_Use_White_Paper_FINAL.pdf and http://files.shareholder.com/downloads/AMERPR/4046241639x0x798496/690877E9-F9D4-4EC2-8324-340C2CCA48F3/Water-Energy_Efficiency-DOE_Fact_Sheet_-_08-2014.pdf.

Reference to a non-federal entity does not constitute an endorsement on the part of DOE or the U.S. government.

2.5 Higher Education Institutions

Increasing energy productivity across all sectors requires a suitably prepared workforce. And, cross-disciplinary coursework is needed to support the needs of emerging areas of energy productivity, such as the Smart Grid, advanced manufacturing, and building energy systems. Strategies in this section were developed using feedback from the regional dialogues, the roundtable discussions, and goal endorsers.Actions taken by higher education institutions contribute to four energy productivity wedges:

Smart Energy Systems
Technologies for Buildings Energy Productivity
Smart Manufacturing
Transportation

2.5.1 WORKFORCE TRAINING

Additional energy productivity gains can come from efficiently operating and maintaining buildings. Building operators can realize annual energy bill savings of 5-20 percent by implementing operations and maintenance (O&M) best practices, including operating equipment only when needed, performing preventative O&M, and tracking performance.[143]

The Building Operator Certification (BOC®) is a training and certification program that provides building operators with the skills and knowledge to implement the types of O&M best practices that can help maximize the efficiency of existing and future buildings. BOC certification is offered by several Regional Energy Efficiency Organizations as well as community and technical colleges in the Northeast, Mid-Atlantic, Southeast, and the West.[144] Annual energy and utility bill savings specific to companies with BOC-certified operators are estimated to be 170,000 kWh per year and $12,000 per year, respectively, which is enough electricity to power nearly 100 refrigerators for a year.[145]

143 "Operations and maintenance reports," Energy Star, accessed July 2015, https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/comprehensive-approach/operations-and; Portland Energy Conservation, Inc., *Fifteen O&M Best Practices for Energy Efficient Buildings* (Washington, D.C.: U.S. Department of Energy and U.S. Environmental Protection Agency, 1999), accessed July 2015, https://www.energystar.gov/sites/default/files/buildings/tools/Fifteen%20O%26M%20Best%20Practices.pdf.

144 "Training Locations & Schedules," Building Operator Certification, last updated August 11, 2015, http://www.theboc.info/h-training-locations.html.

145 "Value & Benefits of BOC," Building Operator Certification, last updated August 24, 2010, http://www.theboc.info/w-value-benefits.html.

While higher education can lead to certain careers that will help accelerate energy productivity, many job opportunities exist in the energy and advanced manufacturing fields that do not require four-year degrees. Technical and community colleges can provide the skills and knowledge for the next generation of energy and manufacturing industry employees. Mississippi's Get on the Grid[146] and Ohio's Advanced Manufacturing Industry Partnership[147] are examples of the types of workforce training programs that can be leveraged to increase energy productivity.

The workforce of an advanced energy economy needs to not only have the skills to operate today's technologies but needs to have the skills and support to make further innovations. Partnerships with industry and businesses, such as the DOE's Building University Innovators and Leadership Development (BUILD) program, can further help support educating and training future innovators in energy productivity.

2.5.2 ACCELERATING ENERGY PRODUCTIVITY FROM THE LAB TO THE REAL WORLD

Colleges and universities are instrumental partners for carrying out federally funded R&D. While the growth of federal R&D funding has largely stagnated since 2004, universities are contributing a larger share of funding and they were responsible for over $12 billion (FY 2014 dollars) of the $64 billion (FY 2014 dollars) total university science and engineering R&D funding in 2012.[148]

Universities can play an important role in transferring innovative technologies to businesses. Universities offer unique opportunities to act as real world testbeds for technologies and practices that increase energy productivity. For instance, the Future Renewable Electric Energy Delivery and Management (FREEDM) System Center, directed by North Carolina State University, supports fundamental research for breakthrough energy storage and power semiconductor technologies as well as partnerships with businesses to facilitate the transition of research into commercially viable products.[149] Several technologies developed by FREEDM have received commercial licenses.[150]

146 "Get on the Grid," Mississippi Energy Institute, accessed July 2015, http://www.getonthegridms.com/.

147 "Advanced Manufacturing Industry Partnership," Partners for a Competitive Workforce, accessed July 2015, http://www.competitiveworkforce.com/Advanced-Manufacturing.html.

148 "R&D at Colleges and Universities,"American Association for the Advancement of Science, last updated August 14, 2015, http://www.aaas.org/page/rd-colleges-and-universities.

149 "About: Center Goals," NSF FREEDM Systems Center, North Carolina State University, accessed July 2015, http://www.freedm.ncsu.edu/index.php?s=1&p=7.

150 NSF FREEDM Systems Center, "FREEDM Marks Progress in Innovation, Economic Impact," news release, undated, http://www.freedm.ncsu.edu/index.php?s=2&t=news&p=184.

HIGHER EDUCATION INSTITUTIONS SUCCESS STORY

North Carolina State University Creates Electricity at Renovated Utility Plant

When North Carolina State University (NC State) faced the challenge of deferred maintenance on equipment in its central utility plants with no available capital funding, university leadership used a $61 million energy performance contract to finance the addition of modern CHP technology. The new CHP facility enables NC State to generate some of its own electricity, and the money the university saves in avoided utility-provided energy costs pays back the loan that financed the CHP technology and boiler replacements.

Founded in 1887, NC State University has a campus community of more than 40,000 students, faculty, and staff in Raleigh. With an annual utility budget of approximately $32 million, the university provides electricity, steam, chilled water, and domestic water to more than 15 million square feet of campus building space.

As do many higher education institutions, NC State faces the challenge of funding vital maintenance on aging buildings and infrastructure, such as utility systems. As several crucial campus boilers exceeded the end of useful life, the university had no capital funding available for the replacement of this equipment. The university also faced challenges related to air quality compliance, as the old boilers relied on #6 fuel oil. NC State needed funding for new, cleaner-burning natural gas boilers and related equipment.

The university turned to an energy performance contract-funding model to finance replacement of critical boilers. A performance contract allows an owner to pay for a renovation through the energy savings generated by efficiency improvements. Using a performance contract, NC State was able to incorporate CHP technology on campus. The $61 million performance contract, financed over 17 years, also allowed the addition of two natural gas fired 5.5-MW combustion gas turbine generators and two 50,000-pound-per-hour heat recovery steam generators to the existing Cates Utility Plant in 2012. The contract also financed replacement of aging boilers, utility interconnects, and auxiliary equipment at the nearby Yarbrough Steam Plant. CHP allows NC State to create its own electricity and converts "waste heat," which would be unused in traditional power plants, into energy. By using this campus-generated energy, NC State buys less energy from local utility companies.

In addition to more reliable steam production and better air quality compliance, the CHP facility reduced energy use and carbon emissions while expanding the university's resiliency and capacity for future growth. In the CHP plant's first two years, more than $10 million of energy costs were avoided and emissions associated with utility production on the university's central and north campuses dropped 24 percent. Educational benefits also resulted. Many NC State engineering students tour the facility to see CHP technology in action. The savings associated with the project have prompted the university to consider adding more CHP capacity at its nearby Centennial Campus utility plant.

An animation of CHP technology on campus is available at sustainability.ncsu.edu/chp/NCSU Case Study.

Reference to a non-federal entity does not constitute an endorsement on the part of DOE or the U.S. government.

2.6 Households

Households account for a large portion of U.S. energy use, and household purchases of goods and services drive much of the U.S. economy. Residential buildings and personal transportation together represented roughly 40 percent of primary energy use in 2014.[151] Household energy use is even more significant when the energy required to produce consumer goods and services, so called "embodied energy," is considered. Also, household expenditures constitute a large portion of overall economic activity.

The concept of household energy productivity may not be as intuitive as it is for a business, but the fundamental aspects are the same. Households can choose to purchase goods and services that allow more productive use of energy in providing services such as transportation, indoor comfort and illumination, and entertainment. However, these purchasing decisions can be clouded by market failures such as incomplete information and split incentives whose remedies may require government policies. Strategies in this section were developed using feedback from the regional dialogues, the roundtable discussions, and goal endorsers. Actions taken by households contribute to two energy productivity wedges:

Technologies for Buildings Energy Productivity
Transportation

2.6.1 ENERGY PRODUCTIVITY AT HOME

Households can reap energy productivity benefits by participating in the *Roadmap* strategies identified for government and businesses. The goal of many of these strategies is to enable households to choose the most energy-efficient products, which translates into savings on energy bills. Purchasing more energy-efficient appliances, in addition to taking other energy efficiency measures such as installing insulation, could reduce household electricity and natural gas use by 34 percent and 35 percent respectively and could result in utility bill savings of $83 billion (in 2007 dollars) by 2030.[152]

151 The sum of residential buildings, light-duty vehicles, bus transportation, passenger rail, and air primary energy use is from U.S. Energy Information Administration, *Annual Energy Outlook 2015 with Projections to 2040* (Washington, D.C.: U.S. Energy Information Administration, 2015), accessed July 2015, http://www.eia.gov/forecasts/aeo/.

152 America's Energy Future Energy Efficiency Technologies Subcommittee, National Academy of Sciences, National Academy of Engineering, and National Research Council, *Real Prospects for Energy Efficiency in the United States* (Washington, D.C.: National Academies Press, 2010).

Many strategies aim to improve the amount and quality of energy information available to households in order to allow consumers to make better-informed decisions on the use of energy in their home and to encourage early adoption of more energy-efficient products. Information-based strategies have been found to reduce electricity use by 7 percent.[153] The federal government provides a suite of websites that address the many facets of household energy efficiency, including homes (http://www.energysaver/.gov) and transportation (www.fueleconomy.gov). Utilities and companies are offering households greater visibility into home energy use. For example, they are providing homeowners and others the option to compare energy use with that of that their neighbors and similar houses.[154] A collaboration of the University of Florida and the International Carbon Bank and Exchange took energy data visibility a step further and created an online platform where anyone can view electricity use and building characteristics of homes in Gainesville, Florida.[155] Initiatives like DOE's Green Button initiative allow households to access their electricity meter data in a standardized format.[156] Green Button also allows users to automatically connect their data to services that will evaluate opportunities to reduce their electric bills.

As many as 37 states and the District of Columbia incentivize the use of EVs.[157] The Federal government and certain states, including California, Colorado, Connecticut, Louisiana, and Maryland, offer rebates or tax credits for purchases of EVs.

153 Magali A. Delmas, Miriam Fischlein, and Omar I. Asensio, "Information strategies and energy conservation behavior: A meta-analysis of experimental studies from 1975 to 2012," *Energy Policy* 61 (2013): 729–739, accessed July 2015, http://dx.doi.org/10.1016/j.enpol.2013.05.109.

154 Research points to the need at some minimal frequency to provide households with reports on their energy use in order for energy savings to persist. See Hunt Allcott and Todd Rogers, "The Short-Run and Long-Run Effects of Behavioral Interventions: Experimental Evidence from Energy Conservation," *American Economic Review* 104:10 (2014): 3003–3037, accessed July 2015, http://dx.doi.org/10.1257/aer.104.10.3003.

155 "Gainesville Green: Your Home Energy Tracking System," Gainesville Green, accessed July 2015, http://www.gainesville-green.com.

156 "Helping You Find and Use Your Energy Data," Green Button Data, accessed July 2015, http://www.greenbuttondata.org/.

157 Kristy Hartman, "State Efforts Promote Hybrid and Electric Vehicles," National Conference of State Legislators, June 29, 2015, http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx.

HOUSEHOLDS SUCCESS STORY

Opower Partners with the Nation's Utilities to Drive Energy Savings through Customer Engagement and Applied Behavioral Science

For utilities around the world, keeping the lights on is no longer enough. The utility industry is now in a time of significant change, and utilities are placing technology at the center of their strategies to navigate the path to a successful future. Today's utility customer only spends about 9 minutes thinking about their energy consumption each year, so utilities are challenged to make every moment of customer contact matter.

By combining data management, analytics, and behavioral science, Opower's customer engagement platform positions utilities as energy advisors to the customers they serve. Opower's technology platform analyzes more than 300 billion meter reads to deliver its services, and created enough energy savings to power all the homes in a city of 1 million people for a year. Opower has facilitated savings over 8 terawatt-hours of electricity to date, which equates to over $1 billion saved by customers on their monthly energy bills, affecting more than 50 million households today.

EXAMPLE: OPOWER'S CUSTOMER ENGAGEMENT PLATFORM

The utility National Grid Massachusetts (National Grid MA) needed to meet a strict state energy efficiency mandate, and traditional solutions like retrofitting and appliance rebates incurred high costs with limited return on investment. Furthermore, National Grid MA wanted to elevate its levels of customer engagement and satisfaction.

Opower's software gave National Grid MA the applications it needed to transform their customer experience. Built specifically for the energy industry, Opower's customer engagement platform met National Grid MA's need by combining the efficiency of the cloud with insightful analytics, applied behavioral science, and great design.

EXAMPLE: OPOWER'S HOME ENERGY REPORT

National Grid MA deployed Opower's Home Energy Report (HER) program, a tailored energy usage evaluation that offers personalized energy-saving tips, anonymously compares customers' energy usage with that of neighbors with similar home size and demographics, and suggests lifestyle changes to reduce their energy consumption. HERs are proven to reduce residential consumption by 1.5-3 percent across a utility's territory, and furthermore have shown to increase positive customer sentiment towards utilities.

Several years after deploying Opower's energy efficiency program in Massachusetts, National Grid MA announced that customers saved over $70 million on their energy bills. Working with Opower, National Grid MA helped customers reduce their electricity usage by 300 million kilowatt hours (kWh) and gas usage by 18 million therms – the equivalent of eliminating more than 300,000 metric tons of carbon dioxide from the environment.

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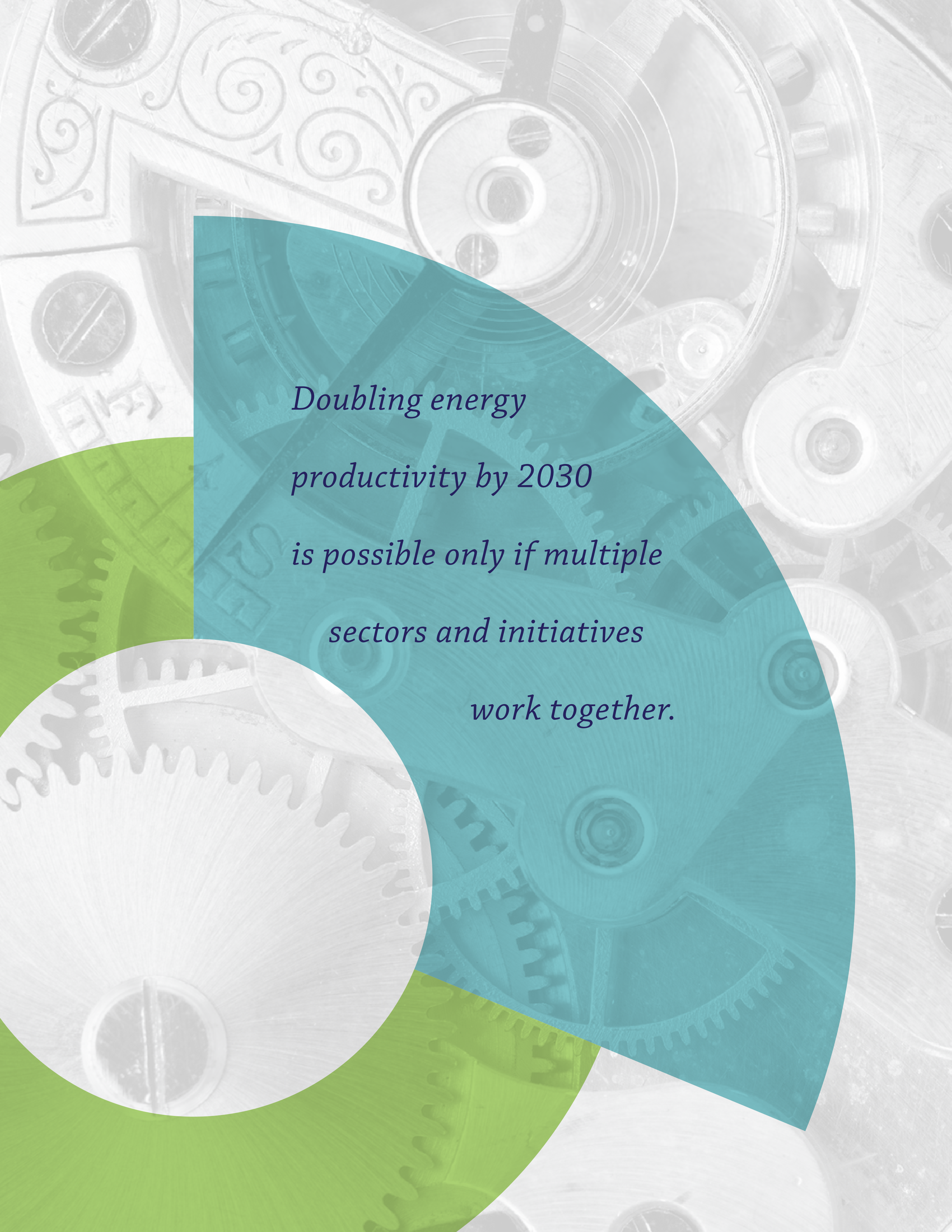

Doubling energy productivity by 2030 is possible only if multiple sectors and initiatives work together.