Energy Efficiency as a Pollution Control Technology and a Net Job Creator under Section 111(d) Carbon Pollution Standards for Existing Power Plants

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Foreword

The American power sector is at the crossroads of disruptive new technologies, major capital investments in modern infrastructure, and the imperative to protect human health and the environment from climate-destabilizing emissions. As states, power companies and environmental advocates work together to cut carbon emissions from our nation's fleet of fossil fuel power plants in the context of these dynamic forces, it is critical that the solutions that make the most sense for consumers are pushed to the forefront.

Energy efficiency has an essential role. Common sense solutions like energy efficiency can cut carbon emissions by using energy systems more productively -- reducing waste and saving American families and businesses money. New information technologies and innovative financing solutions provide unprecedented opportunities to unlock the full potential of energy efficiency – and to do so in alignment with the major cross currents altering the power sector.

Energy efficiency is the most cost-effective means of meeting energy demand and reducing carbon emissions—because investments in energy efficiency more than pay back in energy bill savings. As this report and other empirical evidence demonstrate, energy efficiency investments also create jobs and make our economy more competitive. By investing in energy efficiency now, we can enjoy the immediate environmental, economic, and energy-security benefits while sowing the seeds of future productivity, advanced technologies and prosperity.

As our nation deploys cleaner energy solutions on a large-scale, it is important to ensure that these energy solutions are accessible to all customers—particularly those in our population who are the most vulnerable. And as Skip Arnold, Executive Director of Energy Outreach Colorado, a low-income energy consumer advocacy group, has pointed out, "Without extraordinary treatment, low-income households will not have access to these programs."

Under the newly proposed Clean Power Plan, EPA projects that by investing in energy efficiency household and business energy bills can decrease by about 8% by 2030.[1] *This report shows that savings to families could be significantly greater with greater deployment of energy efficiency—securing a 15% improvement in energy efficiency by 2030 could generate annual average household savings of $157.*

Enabling demand-side energy efficiency to serve as a building block for emissions reductions is a smart option for consumers—but it is critical that as states begin to think about their compliance strategies, the potential for cost savings are translated into lower energy bills for all homes and businesses—especially those in low-income communities.

As Mr. Arnold further notes, "For low-income energy efficiency/demand side management programs that target low-income housing to be effective, they must be implemented differently

[1] EPA, Regulatory Impact Analysis for the Proposed Carbon Pollution Guidelines for Existing Power Plants and Emission Standards for Modified and Reconstructed Power Plants, at 3-43 (June 2014), *available at* http://www2.epa.gov/sites/production/files/2014-06/documents/20140602ria-clean-power-plan.pdf.

than similar programs that serve the general body of residential utility customers. Because of the very limited resources of low-income households and multi-family low-income housing providers, traditional rebate programs won't provide the resources necessary to make energy efficiency improvements to their facilities. In Colorado, and some other states, robust low-income energy efficiency programs delivered by utilities and nonprofit organizations have been implemented that go a long way in addressing this particular issue."

"We believe that there is an opportunity for the EPA to achieve the desired goal of reducing carbon emissions and at the same time lower home energy bills and create a safer, more comfortable home for our most vulnerable neighbors. But in order to do so, it is critical that EPA issues guidance that points to energy efficiency for low-income housing as an important and appropriate measure to achieve the desired goal. And as states look to implement Rule 111(d), ramping up low income energy efficiency programs should become a top priority."

Indeed, the potential for energy efficiency in the multifamily sector may be even greater than in other sectors of the economy: a 2009 study by Benningfield Group estimated the economic energy efficiency potential of multifamily homes at nearly 60%,[2] *compared to 26% in the overall U.S. economy.*[3] *In addition, if states decide to implement market-based measures, they can use the proceeds to help reinvest in energy efficiency and direct bill assistance for those struggling to pay their electricity bills. For example, in the first three years of the Regional Greenhouse Gas Initiative, the ten participating Northeast and Mid-Atlantic states devoted more than $127 million from the auction of allowances to direct bill assistance.*[4]

Many states and power companies have already realized the significant benefits of energy efficiency, setting energy efficiency standards and investing in efficiency retrofits and upgrades of buildings and appliances. But these programs fall far short of capturing our nation's vast energy efficiency resource, and fall short of reaching the potential to drive energy savings and cost savings with the low-income communities that could benefit most from the direct pocket-book savings.

As the Clean Power Plan is finalized, it will be a critical opportunity to mobilize investments in energy efficiency—and through well designed programs such investments can be deployed to ensure that all customers including those facing economic hardship have access to cost-saving and energy-saving programs.

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[2] Benningfield Group, *U.S. Multifamily Energy Efficiency Potential by 2020*, at 4 (Oct. 2009), *available at* http://www.benningfieldgroup.com/docs/Final_MF_EE_Potential_Report_Oct_2009_v2.pdf.

[3] McKinsey & Company, *Unlocking Energy Efficiency in the U.S. Economy*, at 3 exh. A (July 2009), *available at* http://www.mckinsey.com/client_service/electric_power_and_natural_gas/latest_thinking/unlocking_energy_efficiency_in_the_us_economy.

[4] Analysis Group, *The Economic Impacts of the Regional Greenhouse Gas Initiative on Ten Northeast and Mid-Atlantic States: Review of the Use of RGGI Auction Proceeds from the First Three-Year Compliance Period*, at 19, 21 (Nov. 2011), *available at* http://www.analysisgroup.com/uploadedFiles/Publishing/Articles/Economic_Impact_RGGI_Report.pdf.

Executive Summary

This year residences and businesses in the United States will spend an estimated $360 billion to meet our total electricity demands – to cool and light our homes, listen to music or watch television, and power our commercial and industrial equipment. Electricity purchases will further enable our access to the Internet and will filter and purify the water that is delivered to our homes, schools, and businesses each and every day.

Although we will derive many important benefits as we pay our monthly electricity bills, the current electricity generation infrastructure annually produces 3.34 million tons of sulfur dioxide (SO_2) and 1.68 million tons of nitrogen oxides (NO_x) air pollution. These and other pollutants are expected to add $125 billion or more to this year's health care costs. Power plants are also the largest source of climate-disrupting carbon pollution in the United States, emitting an estimated 2 billion metric tons of carbon dioxide (CO_2) each year. Due to human activities—primarily the combustion of fossil fuels and deforestation—the concentration of carbon dioxide and other heat-trapping gases in the atmosphere is rapidly rising. The need to mitigate CO_2 emissions is truly urgent. The emerging evidence has led prominent physicist and climate scientist James Hansen to reach the "startling conclusion" that the continued exploitation of fossil fuels threatens not only the planet, but also the survival of humanity itself.

In June 2013, President Obama directed the U.S. Environmental Protection Agency (EPA) to undertake a rulemaking to establish limits on greenhouse gas emissions from existing power plants under section 111(d) of the Clean Air Act. The language of section 111(d) is sufficiently broad to encompass a flexible, system-based approach to securing carbon pollution reductions from existing power plants. A system-based approach provides an excellent opportunity for EPA to rely on customer friendly end-use energy efficiency as a building block for determining the available emissions reductions and to consider end-use energy efficiency as a compliance mechanism through which the power sector can achieve meaningful, low-cost emission reductions.

In this report we explore whether incentivizing energy efficiency through the carbon pollution standards or other policies also represents an important opportunity for economic growth and job creation. In other words, would more productive use of electricity and reduced levels of waste actually increase our social and economic well-being? Can the billions of dollars spent each year for electricity be used in other ways to more productively strengthen our nation's economy and reduce the harms imposed by fossil fuel fired generation?

The answer is clearly yes. The evidence presented here suggests that a 20 percent electricity savings by the year 2030 can catalyze a large net consumer savings that

- supports a gain of 800,000 jobs for the American economy, while raising wages by almost $45 billion;

- increases GDP by more than $26 billion;

- reduces carbon pollution by 971 million metric tons, and sulfur dioxide and nitrogen oxides by 700,000 and 800,000 tons, respectively.

An expanded emphasis on energy efficiency can extend these benefits across all sectors of the economy.

I. Introduction

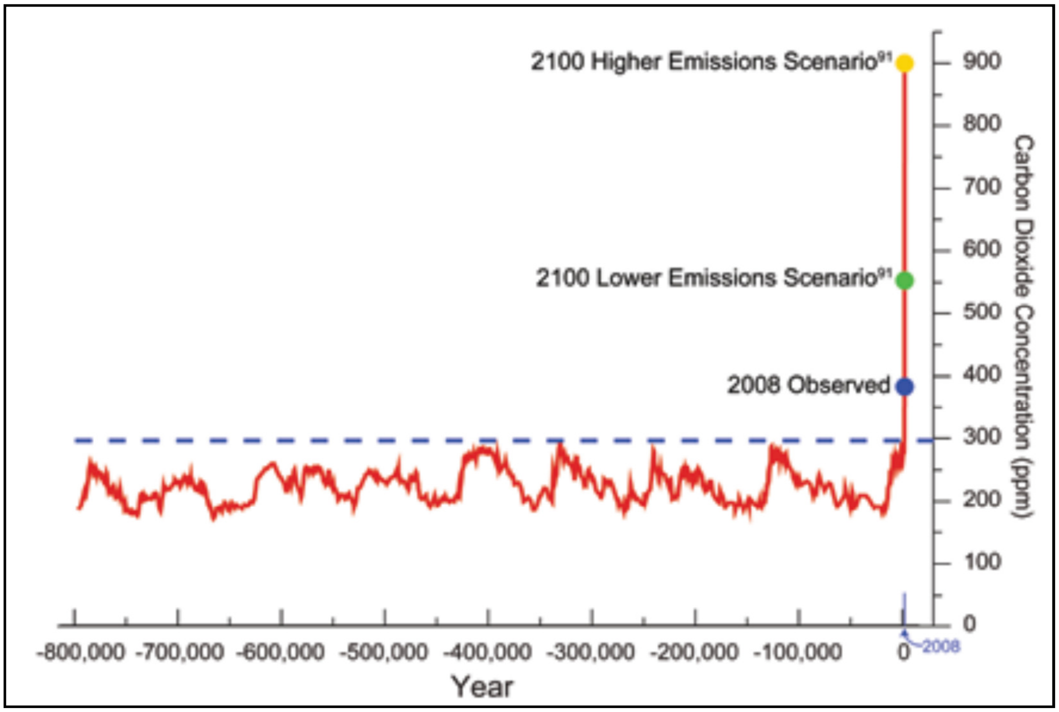
The Urgency of Action

The current electricity generation infrastructure annually produces 3.34 million tons of sulfur dioxide (SO_2) and 1.68 million tons of nitrogen oxides (NO_x) air pollution.[5] These and other pollutants were expected to add $125 billion or more to health care costs in 2013, leading to 18,000 premature deaths, 27,000 cases of acute bronchitis, and 240,000 episodes of respiratory distress. The noxious effects of these pollutants also include 2.3 million lost work days due to illness and as many as 13.5 million minor restricted activity days in which both children and adults must alter their normal activities because of respiratory health problems.[6]

Power plants are also the largest source of climate-disrupting carbon pollution in the United States, emitting an estimated 2 billion metric tons of carbon dioxide (CO_2) each year.[7] Due to human activities—primarily the combustion of fossil fuels and deforestation—the concentration of carbon dioxide and other heat-trapping gases in the atmosphere is rapidly rising. Atmospheric carbon dioxide (CO_2) levels have increased by approximately 38 percent since the Industrial Revolution (see Figure 1); current atmospheric concentrations of both CO_2 and methane (an even more potent greenhouse gas) are significantly higher than they have been for the last 800,000 years.[8]

1. *See* U.S. Dept. of Energy, Energy Info. Admin., *Annual Energy Outlook 2014 with Projections to 2040* (2014) at A19 Table A8, *available at* http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf (hereinafter EIA 2014).
2. *See* Abt Assoc. Inc., *User's Manual for the Co-Benefits Risk Assessment (COBRA) Screening Model (2010)* (author-derived estimates based on emissions scenarios for 2010 given various health effects identified by EPA's Co-Benefits Risk Assessment (COBRA) model).
3. EIA 2014. Electricity production in 2014 represents about 26 percent of our nation's total energy costs but produces 39 percent of our nation's total CO_2 emissions. *Id.* tbls. 3, 18.
4. *See* U.S. Envtl. Prot. Agency, *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act* (2009) at ES-1 to -2 (hereinafter TSD); Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis*, at 512 (S. Solomon et al. eds., 2007) (hereinafter IPCC 2007); U.S. Global Change Research Program, *Global Climate Change Impacts in the United States* (2009) (hereinafter USGCRP 2009).

Figure 1. 800,000-Year Record of Carbon Dioxide Concentration



Source: USGCRP (2009) at 13.

This chart shows a recent, rapid buildup in CO_2 concentrations in the atmosphere relative to the last 800,000 years, based upon analyses of air bubbles trapped in Antarctic ice. It also shows that unless we curb greenhouse gas emissions, atmospheric CO_2 concentrations will likely double or triple by the end of this century from pre-industrial levels.[9]

The increase in the amount of solar radiation that is trapped in the earth's atmosphere due to rising concentrations of greenhouse gases is causing average global temperatures to rise and presents severe risks to the health and well-being of Americans.

Rising temperatures will accelerate ground-level ozone (and smog) formation in polluted areas, and increase the frequency and duration of stagnant air masses that allow pollution to accumulate.[10] Higher ozone levels exacerbate respiratory illnesses, increasing asthma attacks and hospitalizations and increasing the risk of premature death.[11]

Rising temperatures will also result in heat waves that are hotter, longer, and more frequent.[12] Snowpacks will be smaller and snow melt accelerated, threatening water supplies in late summer in the West.[13] In addition, significant reductions in winter and spring precipitation are

5. USGCRP 2009 at 2.
6. TSD at 89-93, USGCRP 2009 at 93-94.
7. Environmental Protection Agency, *Regulatory Impact Analysis for the Proposed Standards of Performance for Greenhouse Gas Emissions for New Stationary Sources: Electric Generating Units* (March 2012) at 3-2 -3-3, 5-24 (hereinafter RIA).
8. IPCC 2007 at 750; 74 Fed. Reg. at 66524-25.
9. USGCRP 2009 at 10, 45-46.

projected for the South, especially in the Southwest, further imperiling water supplies.[14] Rising temperatures will likely increase the frequency, length, and severity of droughts, especially in the West.[15] Precipitation events in general and some types of storms, particularly hurricanes, are expected to become more intense, increasing the likelihood of severe flooding.[16] Water shortages and heavy precipitation events are likely to further stress flood control, drinking water, and wastewater infrastructure.[17]

Global sea levels are likely to rise between seven inches and four feet during the 21st century, both because of ice sheet melting and because seawater expands as it warms.[18] This amount of sea level rise, in combination with more powerful hurricanes, will increase the risks of erosion, storm surge damage, and flooding for coastal communities, especially along the Atlantic and Gulf coasts, Pacific Islands, and parts of Alaska.[19] Under a business as usual emission scenario, what is currently a once-a-century flood in New York City is projected to be twice as common by mid-century and 10 times as frequent by the end of the century.[20] With accelerated sea level rise, portions of major coastal cities, including New York and Boston, would be inundated during storm surges or even during regular high tides.[21] In the Gulf Coast area, an estimated 2,400 miles of major roadways are at risk of permanent flooding within 50 to 100 years due to anticipated sea level rise in the range of 4 feet.[22]

Due to ocean absorption of carbon dioxide, ocean acidity has increased 25 percent since pre-industrial times.[23] If atmospheric carbon dioxide doubles, oceanic acidity will also increase, leaving almost nowhere in the ocean where coral reefs can survive and threatening the ocean's food webs, which rely upon coral reefs as fish nurseries and planktonic animals that may be unable to survive a more acidic sea.[24] The loss of healthy ocean ecosystems would have devastating effects on the global food supply.

In addition, the more temperatures rise, the greater the risk that disruptive climate change thresholds could be reached more quickly. This, in turn, could generate abrupt environmental changes with potentially catastrophic impacts for natural systems and human societies.[25]

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10. USGCRP 2009 at 30; 74 Fed. Reg. at 66,532.
11. USGCRP 2009 at 30, 41-46; IPCC 2007 at 262-263, 783; 74 Fed. Reg. at 66,532-34; RIA at 3-5, 3-8..
12. USGCRP 2009 at 34-36, 44, 64; TSD at ES-4, 115; AR4, IPCC 2007 at 783; 74 Fed. Reg. at 66,525.
13. USGCRP 2009 at 47-51, 132-36; 74 Fed. Reg. at 66,532-33.
14. USGCRP 2009 at 37, 150; AR4, IPCC 2007 at 750.
15. USGCRP 2009 at 12, 36, 109-10, 142-43, 149-50. Super Typhoon Haiyan that roared into the Philippines and Vietnam in early November 2013 provides an unfortunate glimpse of future impacts. Officials predicted that the death toll could exceed 10,000 -- or more. *See* http://www.cbsnews.com/8301-202_162-57611690/typhoon-haiyan-slams-into-northern-vietnam/.
16. USGCRP 2009 at 109-10. "Superstorm Sandy" may be another example of these future impacts. It was the deadliest and most destructive hurricane of the 2012 Atlantic hurricane season, as well as the second-costliest hurricane in United States history. *See* http://en.wikipedia.org/wiki/Hurricane_Sandy.
17. USGCRP 2009 at 150.
18. USGCRP 2009 at 62.
19. RIA at 3-9.
20. RIA at 3-7, 3-9 – 3-10; National Research Council, *Advancing the Science of Climate Change* at 55-56, 59-60 (2010), *available at* http://www.nap.edu/openbook.php?record_id=12782.
21. USGCRP 2009 at 26; National Research Council, *Abrupt Climate Change, Inevitable Surprises* at v, 16, 154 (2002); US Climate Change Science Program, *Abrupt Climate Change* at 10 (2008); TSD at 66.

The need to act to mitigate these harms is truly urgent. These circumstances and the emerging evidence have led prominent physicist and climate scientist James Hansen to reach the "startling conclusion" that the continued exploitation of fossil fuels threatens not only the planet, but also the survival of humanity itself (Hansen 2009 at ix). Furthermore, the continued inefficient use of energy will contribute to a further weakening of the U.S. economy.[26] As we shall see in this analysis, for example, the inefficient use of electricity will cost the economy nationwide an estimated 800,000 jobs by 2030, which means$44 billion in lost wages in that year.

The Opportunity in Acting

There is little question that the production and use of electricity hold great economic value for the United States. But there is also little question that the current infrastructure of fossil fuel fired electricity generation and electricity usage patterns are imposing heavy burdens on Americans in the form of health impacts, climate destabilization, water consumption, and job loss. In this report we ask the question of whether there is an opportunity cost being overlooked by current patterns of production and consumption of electricity. In other words, can more productive use of electricity and reduced waste actually increase our social and economic well-being? In short, can the billions of dollars spent each year for electricity be used in other ways to strengthen our nation's economy and reduce the harms imposed by fossil fuel fired generation? The answer is clearly yes.

In this working paper we set out to explore two questions. First we ask: How big is the energy efficiency resource? That is, how big of a benefit can energy efficiency deliver if seen as a pollution control strategy? And what scale of investment is required to drive reductions in conventional air pollution as well as greenhouse gas emissions? Second, we provide a first order review of the jobs and economic impacts of efficiency-led emissions reductions. We provide an initial estimate of cost-effectiveness of the energy efficiency resource, and then explore how that change in spending might impact the nation's ability to support a greater number of jobs. With that backdrop, Section II of this paper examines the evidence of previous assessments to identify both the scale and the cost-effectiveness of energy efficiency in ways that might inform our investigation here. In Section III we provide an overview of the methodology we use to estimate the economic impacts of increased investment in energy efficiency. Section IV summarizes the major results of this inquiry while Section V offers several conclusions and observations. Section VI identifies the many references that guided our inquiry. Finally, Appendix A provides an extended review of the energy efficiency resource while Appendix B presents further details about the economic model used to complete this assessment.

22. Laitner 2013.

II. The Energy Efficiency Resource Potential

Energy efficiency has played a surprisingly enduring and critical role in our nation's economy. Efficiency is an incredibly low-cost resource and its benefits are wide-ranging and significant. These benefits include both reduced energy bills and a surprising number of non-energy benefits, from reduced operations and maintenance costs at industrial plants to improved quality and speed in the production of our nation's goods and services.[27] Not only could energy efficiency drive down emissions, mitigate adverse health effects, and bring down health costs associated with "business-as-usual" energy use, but these more productive investments could also stimulate a more robust economy by reducing the cost of energy services and spurring job creation.[28]

When it comes to the energy efficiency resource potential, current investments are still just scratching the surface. Building on Ayres and Warr (2009), [29] Laitner (2013) estimates that the U.S. economy is about 14 percent energy (in)efficient, with 86 percent of applied energy wasted in the production of goods and services.[30] What we waste in the generation and use of electricity is more than Japan needs to power its entire economy. Some progress has been made, however: investments in greater energy productivity, since 1970, have resulted in the U.S. economy consuming half the energy it would have otherwise required in 2010.[31]

Energy efficiency is a dynamic and long-term resource, as more fully described in Appendix A.[32] In fact, a McKinsey study estimates that, if executed at scale, a holistic approach to efficiency would yield gross energy savings worth more than $1.2 trillion, an amount well above the $520 billion needed through 2020 for upfront investment in efficiency measures (excluding program costs).[33] Such a program is estimated to reduce end-use energy consumption in 2020 by 9.1 quads, roughly 23 percent of projected demand, potentially abating up to 1.1 gigatons of greenhouse gases (GHG) annually.[34] However, the full energy efficiency potential includes more than simply the penetration of known advanced technologies. If we were to embrace a greater rate of infrastructure improvements along with

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23. *See* Lazard, Ltd., "Levelized Cost of Energy Analysis—Version 7.0" (2013).
24. By reducing U.S. energy use by 30 percent in 2020 and 55 percent in 2050, Laitner et al. (2010) estimate a range in savings per household from $81 in 2020 to $849 per household in 2050 as well as an increase in net jobs from 373,000 jobs created in 2020, 689,000 in 2030, and over 1.1 million in 2050.
25. Ayres, Robert U. and Benjamin Warr. *The Economic Growth Engine: How Energy and Work Drive Material Prosperity*. Northampton, MA: Edward Elgar Publishing, Inc., 2009 (hereinafter Ayres and Warr 2009).
26. *See* John A. "Skip" Laitner, *Linking Energy Efficiency to Economic Productivity: Recommendations for Improving the Robustness of the U.S. Economy* (2013); *see also* Robert U. Ayres and Benjamin Warr, *The Economic Growth Engine: How Energy and Work Drive Material Prosperity* (2009).
27. *See* John A. "Skip" Laitner et al., *The Long-Term Energy Efficiency Potential: What the Evidence Suggests* (2012) (hereinafter Laitner et al. 2012). One quad is a quadrillion Btus which, in the form of gasoline, is sufficient energy to energy to power about 12 million cars and trucks for one year of driving. In other forms of energy one quad is sufficient maintain about 5.4 million homes at current levels of consumption.
28. *See* Amory Lovins, *Reinventing Fire: Bold Business Solutions for the New Energy Era* (2011); Laitner et al. 2012; Hannah Choi Granade et al., *Unlocking Energy Efficiency in the U.S. Economy* (2009) (hereinafter Granade et al. 2009).
29. Granade et al. 2009.
30. Granade et al. 2009. The U.S. now emits about 6.6 billion tons or gigatons of total greenhouse gas emissions per year.

some displacement of the existing capital stock to make way for newer and more productive energy efficiency technologies, as well as new configurations of the built environment that reduce the distance people and goods must be transported, by 2050, we might achieve a 59 percent reduction in total energy use compared to the business as usual Energy Information Administration projection (consuming only 50 quads versus 122 quads by the year 2050).[35]

Reducing electricity demand through energy efficiency and demand side energy management—using only available technologies—has been demonstrated to be one of the most cost-effective means of reducing GHG emissions from the power sector.[36] The 2009 McKinsey study found that, after taking into account the upfront costs of installing efficiency improvements, the efficiency measures they identified would save American families and businesses $680 billion over ten years.[37] In addition, the study estimated that it would require 600,000 to 900,000 workers during the duration of the 10-year period to develop, produce, and implement the efficiency improvements, administer the programs, and verify the results.[38] Simply put, demand side energy efficiency offers tremendous potential to reduce power sector greenhouse gas emissions while simultaneously reducing utility bills for American families and businesses, improving grid reliability, reducing co-pollutant emissions, improving energy security, and creating jobs in the energy efficiency sector.

An extensive body of studies developed over many years suggests that energy efficiency can provide perhaps the largest single source of GHG emissions reductions in the coming decades.[39] Should we reduce electricity use by just 0.1 percent per year between now and 2050,[40] a recent study by Synapse Energy Economics indicates that by 2020, power sector CO_2 emissions would fall 25 percent below 2010 levels.[41] By 2050, the combination of energy efficiency and a variety of renewable energy technologies could reduce CO_2 emissions to 81 percent below 2010 levels.[42] By pursuing the larger achievable efficiency and renewable energy targets, the Synapse assessment also found that other environmental and health impacts of coal-fired electricity are dramatically reduced. Over $450 billion in health effects

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31. Laitner et al. 2012.
32. The Analysis Group notes that "RGGI investment in energy efficiency depresses regional electrical demand, power prices, and consumer payments for electricity. This benefits all consumers through downward pressure on wholesale prices, yet it particularly benefits those consumers who actually take advantage of such programs, implement energy efficiency measures, and lower both their overall energy use and monthly energy bills. These savings stay in the pocket of electricity users. But positive macroeconomic impacts exist as well: the lower energy costs flow through the economy as collateral reductions in natural gas and oil consumption in buildings and increased consumer disposable income (from fewer dollars spent on energy bills), lower payments to out-of-state energy suppliers, and increased local spending or savings. Consequently, there are multiple ways that investments in energy efficiency lead to positive economic impacts; this reinvestment thus stands out as the most economically beneficial use of RGGI dollars." *See* Hibbard et al. 2011.
33. Granade et al. 2009.
34. Granade et al. 2009.
35. Laitner et al. 2012; *see also* L.D. Harvey, *Energy Efficiency and the Demand for Energy Services* (2010); Comm. on America's Energy Future, *Real Prospects for Energy Efficiency in the United States* (2010); Granade et al. 2009; American Physical Society, *Energy Future: Think Efficiency* (2008).
36. Resulting in energy consumption of 3,760 billion kilowatt-hours (kWh) in 2050 versus 5,590 billion kWh under a business-as-usual (BAU) projection.
37. *See* Geoff Keith et al., *Toward a Sustainable Future for the U.S. Power Sector: Beyond Business as Usual 2011* (2011) (hereinafter Keith et al. 2011).
38. Keith et al. 2011.

related to air pollution would be avoided over the 2010 to 2050 study period, based on damage factors developed by the National Research Council.[43]

The evidence indicates that energy efficiency is not only a significant resource, but it also presents an immensely cost-effective pollution control strategy—with benefits exceeding costs over the investment life of individual measures or improvements. A study by the Lawrence Berkeley National Laboratory demonstrated that one-third of electricity and natural gas use in buildings could be saved (along with respective emissions) at a total cost of 2.7 cents per kilowatt-hour (¢/kWh) for electricity and between 2.5 and 6.9 dollars per million Btu for natural gas (all values in 2007 dollars).[44] The study suggested that the cost savings over the life of the measures would be nearly 3.5 times larger than the up-front investment required (in other words, a benefit-cost ratio of 3.5). At the same time, Amann (2006) suggests that non-energy benefits of energy efficiency upgrades might range from 50 to 300 percent of household energy bill savings.[45] These added benefits range from financial savings to energy bill relief, comfort, aesthetics, noise reduction, health and safety, and convenience. Worrell et al. (2003) and Lung et al. (2005) found comparable non-energy benefits that greatly enhance the cost-effectiveness of energy efficiency within the industrial sector as well.[46]

Indeed, efficiency has shown an ability to drive down emissions and mitigate health costs associated with "business as usual" energy use. But, efficiency has also demonstrated its ability to stimulate economic growth by reducing the cost of energy services and spurring job creation. ACEEE demonstrated efficiency's significant macroeconomic impact through its analysis under two policy scenarios: the Advanced Case (42 percent energy savings from 2050 reference case) and the Phoenix Case (59 percent energy savings from 2050 reference case).[47] The study suggested the cumulative capital investments in the efficiency upgrades for the Advanced Case will be about $2.4 trillion over the 39-year period 2012 to 2050 (in constant 2009 dollars). The significantly greater magnitude of efficiency changes in the Phoenix Case increases cumulative investments to $5.3 trillion in that same time period.[48] While this may seem like a significant investment, it is but a fraction of the $4.6 trillion per year the economy is likely to invest over this same time horizon.[49]

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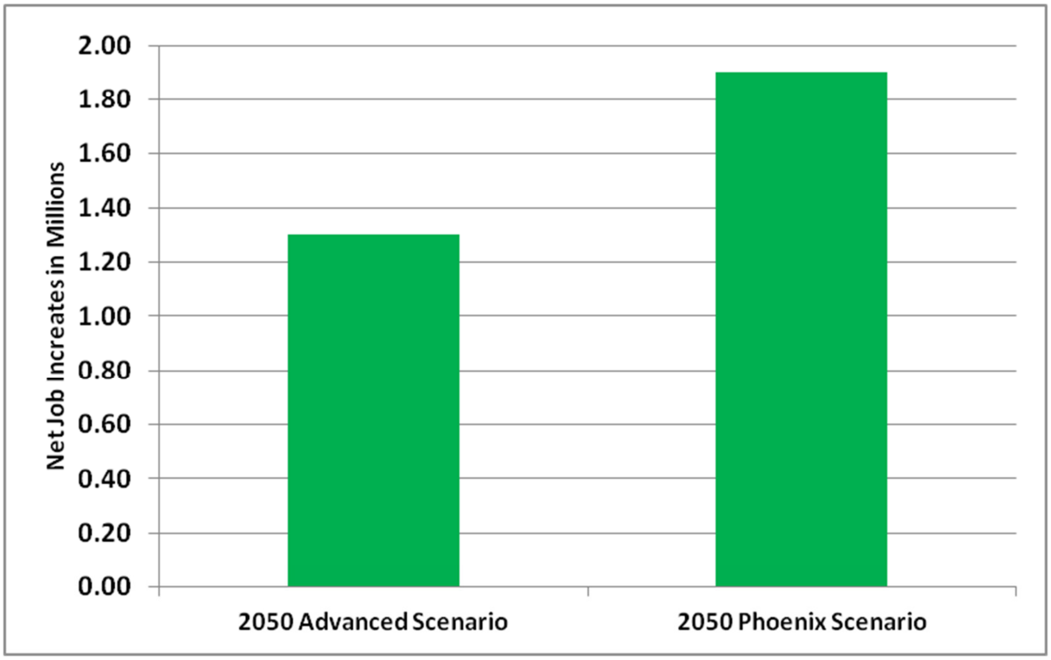
39. *Id.*
40. Rich Brown et al., *U.S. Building-Sector Energy Efficiency Potential* (2008). In 2012, the end-use price of electricity for the residential sector was 11.9¢/kWh in 2012 cents (about 10¢ in 2007 cents); in the commercial sector, 10.1¢/kWh in 2012 cents (about 9¢ in 2007 cents). AEO 2014 tbl. 8. The Henry Hub price for natural gas in April 2014 was $4.66/MMBtu, or, in 2007 dollars, $4.07. EIA, Henry Hub Natural Gas Spot Price, http://www.eia.gov/dnav/ng/hist/rngwhhdM.htm (last visited May 23, 2014); Bureau of Labor Statistics, CPI Inflation Calculator, http://data.bls.gov/cgi-bin/cpicalc.pl.
41. Jennifer Amann, American Council for an Energy-Efficient Economy, *Valuation of Non-Energy Benefits to Determine Cost-Effectiveness of Whole House Retrofit Programs: A Literature Review* (2006).
42. Ernst Worrell et al., "Productivity Benefits of Industrial Energy Efficiency Measures," *Energy*, 1081-98 (2003); Robert Lung et al., American Council for an Energy-Efficient Economy, "Ancillary Benefits and Production Benefits in the Evaluation of Industrial Energy Efficiency Measures" (2005).
43. Laitner et al. 2012.
44. See Table 2 following the discussion in section III for a further comparison of this set of efficiency scenarios with three other long-term efficiency scenarios out to 2050.
45. Laitner et al. 2012. While energy efficiency appears significantly more costly under the Phoenix Scenario, it is roughly the equivalent of just one year's routine investment spread out over a 39-year period.

Figure 2: Net Employment Benefits from Two Efficiency Policy Scenarios



Source: Laitner et al. 2012

The capital investments in efficiency generate substantial cumulative energy bill savings of $15 trillion in the Advanced Case and $23.7 trillion in the Phoenix Case (also in 2009 dollars). Hence, energy efficiency not only proves to be a prudent investment, but it also delivers substantial economic savings that would drive a significant increase in overall employment (see Figure 2 above). The Advanced Case shows that investment in efficiency would produce a 1.3 million job gain in the year 2050. Perhaps unsurprisingly, efficiency investment in the Phoenix Case, benefiting from a larger investment and a bigger net energy bill savings, generates about a 1.9 million job gain in 2050.[50]

III. Assessing Total Employment Impacts

Having established that energy efficiency is an indispensable and cost-effective resource to reduce air pollution and greenhouse gas emissions, we now provide an analytical framework to evaluate the net economic and employment impacts of this resource. We utilize the U.S. Energy Information Administration's annual modeling to establish a reference case, or "business as usual" (BAU) scenario. We compare this to an "Efficiency-Led Scenario" in which the country moves toward a power system based on more productive investments in energy efficiency technologies, systems, and infrastructure. In this alternative scenario, a greater level of energy-efficient investments enables both new demands for energy services and the retirement of some existing electricity generation power plants. In this section we lay out three elements that form the basis of our assessment: (1) the standard projection for U.S. electricity consumption over the period 2012 through 2030; (2) the key characteristics of the alternative

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46. Laitner et al. 2012.

investment scenario; and finally, (3) a description of the DEEPER modeling system used to evaluate the efficiency scenarios characterized in this report.

A. The Business-as-Usual Backdrop

The foundation for this assessment is the *Annual Energy Outlook* published by the Energy Information Administration (2012).[51] Although the forecast of energy and other market trends covers all uses of energy within our economy (including transportation fuels, natural gas, and other resources), here we will explore possible changes in our nation's electricity use beginning in 2012 through the year 2030. This includes the growth in the number of households, commercial, and industrial customers over that time along with the anticipated growth in the demand for electricity services by those users. It also includes both expected trends in electricity prices as well as a discussion of potential drivers of important shifts in electricity demand. In addition, since we are exploring the impacts on the economy, we will review the anticipated growth in the nation's jobs and Gross Domestic Product (GDP), also through the year 2030. Table 1 below provides the assumed reference case projections for key metrics against which we will compare the impacts of an efficiency-led scenario.

Table 1. Reference Case Projections for Key Economic Metrics 2012 and 2030

Metric	2012	2030	Annual Rate	Total Growth
The Macroeconomy				
GDP (billion 2005 dollars)	13,486	21,736	2.7%	61.2%
Real Investment (billion 2005 dollars)	1,875	4,066	4.4%	116.9%
Households (millions)	116.1	139.3	1.0%	20.0%
Nonfarm Employment (millions)	131.8	162	1.2%	22.9%
Electricity Sales				
Economy-Wide Electricity Use (billion kWh)	3,729	4,258	0.7%	14.2%
Average Retail Electricity Price (2010 $/kWh)	0.096	0.098	0.1%	2.1%
Annual Electricity Costs (billion 2010 dollars)	358.0	417.3	0.9%	16.6%
Emissions from Power Plants				
Sulfur Dioxide (million short tons)	3.79	1.62	-4.6%	-57.3%
Nitrogen Oxides (million short tons)	1.99	1.94	-0.1%	-2.6%
Carbon Dioxide (million metric tons equivalent)	2,146	2,258	0.3%	5.2%

Source: EIA (2012)

The summary in Table 1 above forecasts several positive trends even under the reference scenario. First, EIA projects the economy will grow at a faster clip than either the number of households or their increased use of electricity consumption, as measured by EIA's assessment of the nation's GDP. Jobs will also increase. While electricity expenditures will grow as well, they will rise more slowly than GDP. EIA's forecast clearly anticipates that the economy will make increasingly efficient use electricity to provide the nation's homes and businesses with needed goods and services.

47. As the project first began, we originally benchmarked the analysis described here to the energy and economic projections found in the *Annual Energy Outlook 2012* (EIA 2012). While we cite the updated information contained in *Annual Energy Outlook 2013* (EIA 2013), our analysis is still linked to EIA 2012. A series of quick diagnostic tests shows this does not materially impact the findings of this assessment.

Yet the business-as-usual rate of efficiency improvement still requires an increase in overall electricity consumption since the economy is projected to grow more quickly than the rate of efficiency improvement. While pollution control technologies are likely to reduce future air pollution from emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x), as shown in Table 1, carbon dioxide (CO_2) emissions are likely to increase due to the increased fossil fuel combustion associated with the generation of electricity.[52]

Fortunately, we can do much better. We can reduce overall pollution levels and, at the same time, lower the nation's total electricity bill. The many studies summarized in Section II of this report indicate that a much larger set of energy efficiency gains beyond the business-as-usual improvements is possible. This is true for the residential, the commercial, and the industrial sectors of the economy. For example, if the energy efficiency opportunities highlighted in the study by Laitner et al. (2012) were to be developed and implemented, the total electricity demand for 2030, as shown in Table 1, would *decline* to 3,370 billion kilowatt-hours rather than *increase* to 4,258 billion kilowatt-hours. [53] What may be less obvious, however, is that the efficiency gains will prove to be less expensive than increasing the generation capacity to meet the higher electricity demands.

Finally, some readers may be surprised to learn how much the economy depends every year on the flow of normal investments as they affect our nation's homes, schools, businesses, roads, and bridges, as well as the many electric power plants, transmission lines, and industrial facilities needed to maintain a functioning economy. In Table 1 it appears that we will invest about $1,875 billion in new buildings and infrastructure, or in routine upgrades to existing infrastructure. By 2030 this will grow to an estimated $4,066 billion or about 18.7 percent of GDP. As we might imagine, and as shown in the analysis that follows, redirecting even one percent of the nation's annual investment to greater gains in electricity efficiency can provide the foundation to achieve a significant level of cost savings compared to the normal rate of energy efficiency improvements. In addition, as we shall also see, more productive investments will drive a small but positive gain in the nation's job market and achieve a cost-effective reduction in the nation's air pollution and greenhouse gas emissions. The next section of this working paper explores the cost and performance characteristics that might contribute to cost-effective electricity reductions in our homes, schools and businesses.

B. Key Attributes of the Energy Efficiency Scenario

In this assessment, we draw upon two previously referenced studies to define an exploratory scenario that helps evaluate energy efficiency as a pollution control strategy; and, more critically, to explore how energy efficiency investments might drive both significant cost savings

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48. Including transportation and other fuels such as natural gas, the energy-related CO_2 emissions are projected to grow from 5,570 to 5,670 million metric tons at a time when the scientific evidence suggests the need for very steep reductions in greenhouse gas emissions. As noted previously, total greenhouse gas emissions are estimated to be just under 7,000 million metric tons (or gigatons). The difference is the number of other non-energy-related CO_2 emissions which also contribute the total mix of greenhouse gases emitted each year.
49. Laitner, John A. "Skip," Steven Nadel, R. Neal Elliott, Harvey Sachs, and Siddiq Kahn. 2012. *The Long-Tern Energy Efficiency Potential: What the Evidence Suggests*. Washington, DC: American Council for an Energy-Efficient Economy.

and overall gains in employment. The first assessment is from Laitner et al. (2012), which explored the long-term energy efficiency potential for two scenarios through the year 2050. [54] That report examined a more complete set of efficiency options, including natural gas and petroleum efficiency improvements as well as electricity savings from all sectors of the economy. The second is Keith et al. (2011), a report from Synapse Energy Economics that focused explicitly on electricity savings alone.[55] Both assessments found that productive investments in energy efficiency upgrades generated a net positive economic benefit. Although both studies indicate that electricity savings of 30 to 37 percent from the reference case projected for 2050 are possible, the central case of this analysis is an assessment of the economic impacts of achieving a 20 percent efficiency gain by 2030.

To provide a sense of scale and cost-effectiveness of the efficiency resource more broadly, Table 2 highlights key metrics from both the ACEEE and Synapse scenarios. We also include two other studies: the *Energy Technology Perspectives* study published by the International Energy Agency (IEA/ETP 2010) and *Reinventing Fire* released by Lovins et al. (2011). [56]

Table 2. Key Metrics from Year 2050 Alternative Energy Future Studies

Metric	Year 2050 Impacts				
	ACEEE-Advanced	ACEEE-Phoenix	IEA ETP	Reinventing Fire	Synapse[1]
BAU GDP Index (2010 = 1.00)	2.79	2.79	1.95	2.58	2.71
BAU Energy Use (2010 = 1.00)	1.24	1.24	1.05	1.27	1.41
Efficiency Scenario Energy Use (2010 = 1.00)	0.72	0.51	0.47	0.69	0.67
Investment (Trillion 2009 Dollars)[2]	2.9	6.4	5.9	4.5	1.4
Savings (Trillion 2009 Dollars)[2]	15.0	23.7	15.1	9.5	4.4
Index Savings to Investment[3]	5.2	3.7	2.6	2.1	3.5

Table Notes: (1) While the first four studies reflect economy-wide energy savings, the Synapse report captures only the savings from electricity production and consumption. (2) The investments and savings data reflect cumulative values in constant dollars over the period 2010 through 2050. (3) The savings to investment index is a simple comparison of suggested energy bill savings compared to the total cost of investments, also over the period 2010 through 2050. Because there is no way to compare the discounted streams of savings and expenditures over time, this simple index is indicative of, but should not be construed as, a true benefit-cost ratio.

Interestingly, there is a wide range in the assumed future GDP growth among the five scenarios outlined in Table 1. The IEA projects an economy in 2050 that is about 1.95 times bigger than in 2010. ACEEE and Synapse, generally following the EIA's *Annual Energy Outlook*, suggest economic activity that will be 2.71 to 2.79 times larger than 2010. Reinventing Fire suggests a more moderate growth path so that economic activity is 2.58 times larger in 2050 compared to 2010. In comparing the business-as-usual energy growth in

50. Laitner, John A. "Skip," Steven Nadel, R. Neal Elliott, Harvey Sachs, and Siddiq Kahn. 2012. *The Long-Tern Energy Efficiency Potential: What the Evidence Suggests*. Washington, DC: American Council for an Energy-Efficient Economy.
51. Keith et al. 2011.
52. [IEA/ETP] International Energy Agency, Energy Technology Policy Division. 2010. *Energy Technology Perspectives: Scenarios & Strategies to 2050.* Paris, France: International Energy Agency; Lovins, Amory and the Rocky Mountain Institute. 2011. *Reinventing Fire: Bold Business Solutions for the New Energy Era*. White River Junction, VT: Chelsea Green Publishing.

the five scenarios with their respective 2050 efficiency gains, the evidence suggests potential 2050 savings that range between 42 and 59 percent.[57] Moreover, all of the scenarios suggest a net positive savings to investment ratio, ranging from 2.1 to 5.2 over the period of analysis within each scenario. To test the idea of how effective efficiency might be as a pollution control strategy, but reflecting larger uncertainties in the out-years, we take the analysis here to only 2030.

Our core scenario for this exploration assumes an electricity savings that, beginning in 2014, slowly ratchets up to reach 20 percent by 2030. The benefit-cost ratio of this scenario (as we shall see) is over 2.0. As we explain further in the section that follows, we assume that program costs will drive investments that, in turn, generate a 20 percent reduction in conventional electricity generation by 2030 so that the electricity savings, in constant dollars, are twice as large as the combination of program costs and investments, also in constant dollars.

We next turn to a description of the Dynamic Energy Efficiency Policy Evaluation Routine, or the DEEPER, Modeling System, which, in essence, is an econometric input-output analytical tool. Although recently given a new name, the model's origins can be traced back to modeling assessments that were first completed in the early 1990s (see Appendix B for historical information and other details on the DEEPER model).

C. Review of the DEEPER Economic Policy Model

The DEEPER model is "quasi-dynamic" in that the costs of energy efficiency improvements are based on the level of efficiency penetration over some period of time. The greater the efficiency penetration, the higher the costs, and the resulting payback periods begin to increase. Moreover, the model adjusts labor impacts given the anticipated productivity gains within key sectors of the U.S economy. As an example, if the construction and manufacturing sectors increase their output as a result of the alternative policy scenario, the employment benefits are likely to be affected – depending on assumptions about the expected labor productivity gains within each of those sectors.

Input-output models initially were developed to trace supply linkages in the economy. For instance, an input-output accounting framework can show how purchases of lighting technologies or industrial equipment benefit the lighting and other equipment manufacturers in a state. In addition, because the input-output model has coefficients linking both directly and indirectly affected industries, the model can also reveal the multiplicative impacts that such purchases are likely to have on other industries and businesses that might supply the necessary goods and services to those manufacturers.

The net economic gains of any new investments in energy efficiency will depend on the structure of the economy, and which sectors are most affected by changes in new spending patterns that are promoted by investments in energy productivity rather than electricity supply.

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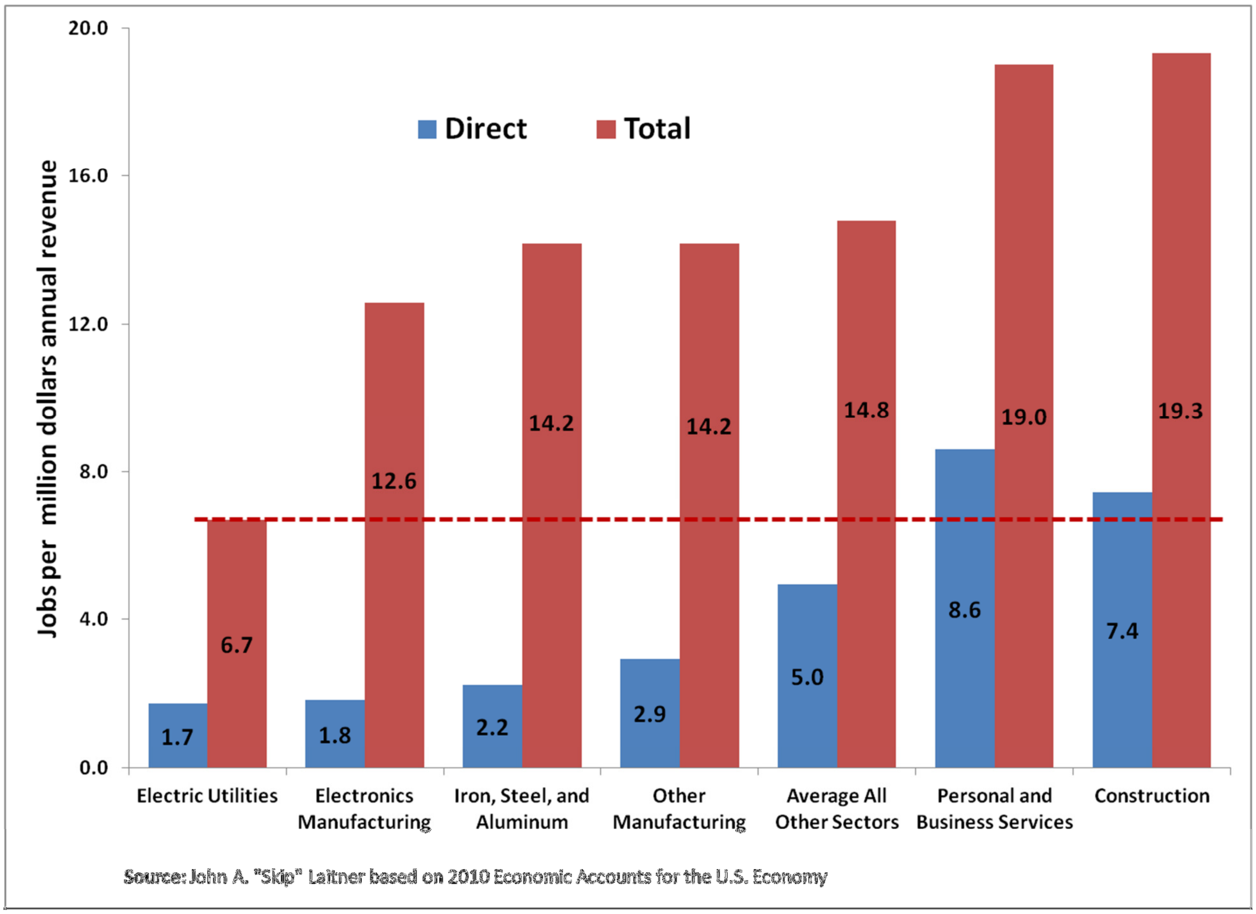
53. As an example, the Synapse study projects a BAU energy growth index of 1.41, with an efficiency use index that falls to 0.67. Hence, (0.67 / 1.41 – 1) *100 percent = 52 percent.

To illustrate this point, Figure 3, below, compares the direct and total employment impacts that are supported for every one million dollars of revenue received by different sectors of the U.S. economy. These include electric utilities, manufacturing, personal and business services, and construction.[58] For purposes of this study, a job is defined as sufficient economic activity to employ one person full-time for one year.

Figure 3. Labor Intensities for Key Sectors of the U.S. Economy



Of immediate interest in Figure 3 is the relatively small number of direct and total jobs supported by energy sector spending. Within the United States the electric utility industry provides, for example, only 6.7 total jobs per million dollars of revenues that it receives. This total includes jobs directly supported by the industry as well as those jobs linked to businesses which, in turn, provide goods and services to maintain the utilities' operation. And it also includes the additional jobs supported by the respending of wages within the U.S. economy.

54. The model used for the assessment described here relies on the IMPLAN datasets for the United States. IMPLAN stands for "IMpact Analysis for PLANning." These 2010 historical economic accounts (IMPLAN 2012) provide a critical foundation for a wide range of modeling techniques, including the input-output model used as a basis for the assessment described here. For more information on the use of this kind of analysis, see the discussion in Appendix B of this report. For a more recent example of an assessment undertaken in the policy arena, see Busch et al. (2012) for an analysis of the recently adopted fuel-economy standards.

On the other hand, one million dollars spent in construction supports a total of 19.3 jobs, both directly and indirectly.

As it turns out, much of the job creation from energy efficiency programs is derived by the difference between jobs within the utility supply sectors and jobs that are supported by the respending of energy bill savings in other sectors of the economy.

D. An Illustration: Jobs from Improvements in Commercial Office Buildings

To illustrate how a simplified job impact analysis might be done, we will use the example of installing one million dollars of efficiency improvements in a large office building. Office buildings (traditionally large users of energy due to heating and air-conditioning loads, significant use of electronic office equipment, and the large numbers of persons employed and served) provide substantial opportunities for energy-saving investments. The results of this example are summarized in Table 3 below.

The assumption used in this example is that the investment has a positive 4-year payback. In other words, the assumption is that for $1 million of energy efficiency improvements, the upgrades might be expected to save an average of $250,000 in reduced electricity costs over the useful life of the technologies. This level of savings is conservatively low but consistent with the low end of ranges cited elsewhere in this report. At the same time, if we anticipate that the efficiency changes will have an expected life of roughly 15 years, then we can establish a 15-year period of analysis. In this illustration, we further assume that the efficiency upgrades take place in the first year of the analysis, while the electricity bill savings occur in years 1 through 15. Moreover, we assume that only half the savings occur in the first year as it may take several months to actually start an average project with savings not beginning until halfway through the year.

Table 3. Job Impacts from Government Building Energy Efficiency Improvements

Expenditure Category	Amount (Million $)	Employment Coefficient	Job Impact
Installing Efficiency Improvements in Year 1	1.0	19.3	19.3
Diverting Expenditures to Fund Efficiency Improvements	-1.0	14.8	-14.8
Energy Bill Savings in Years 1 through 15	3.6	14.8	53.3
Lower Utility Revenues in Years 1 through 15	-3.6	6.7	-24.1
Net 15-Year Change			33.7

Note: The employment multipliers are taken from the appropriate sectors found in Figure 2. Based on the efficiency costs described in the text, the annual savings are about $250,000 with only one-half available in the first year. The jobs impact is the result of multiplying the row change in expenditure by the appropriate row multiplier. On average, this building upgrade would be said to support a net gain of about 2.2 jobs per year for 15 years. For more details, see the text that follows.

The analysis further assumes that we are interested in the *net effect* of employment and other economic changes. This means we must first examine all changes in business or consumer expenditures—both positive and negative—that result from a movement toward energy efficiency. Each change in expenditures must then be multiplied by the appropriate multiplier (taken from Figure 3) for each sector affected by the change in expenditures. The sum of these products will then yield the net result.

In our example, there are four separate changes in expenditures, each with their separate effect. As Table 3 indicates above, the overall impact of the scenario suggests a gain of 33.7 job-years (rounded) in the 15-year period of analysis. This translates into an average gain of about 2.2 jobs each year for 15 years. In other words, the efficiency investment made in the office building is projected to sustain an average gain of 2.2 jobs each year over a 15-year period compared to a "business-as-usual" scenario. Roughly speaking, if comparable projects like this scaled to more like $100 million in a single year, the number of jobs gained would similarly scale upward (to 3,370 job-years).[59]

E. Appropriate Modifications in the Energy Efficiency Scenarios

The economic assessment of the alternative energy scenarios was carried out in a very similar manner as the example described above. That is, the changes in energy expenditures brought about by investments in energy efficiency and renewable technologies were matched with their appropriate employment multipliers. There are several modifications to this technique, however.[60]

First, it was assumed that only 90 percent of both the efficiency investments and the subsequent savings are spent within the United States. We based this initial value on the 2010 IMPLAN dataset as it describes local purchase patterns that typically now occur in the United States. We anticipate that this is a conservative assumption since most efficiency projects are likely to be (or could be) carried out entirely by contractors and dealers within the United States. By way of illustration, if the share of domestic spending turned out to be 100 percent, for example, the overall job gain might grow another five percent or more compared to our standard scenario exercise.

Second, an adjustment in the employment impacts was made to account for assumed future changes in labor productivity. As outlined in the Bureau of Labor Statistics *Outlook 2010–2020*, productivity rates are expected to vary widely among sectors.[61] For instance, the BLS projects an economy-wide 1.5 percent annual average productivity gain as the economy better integrates information technologies and other improvements. To illustrate the impact of productivity gains on future employment patterns, let us assume a typical labor productivity increase of 2.2 percent per year. This means, for example, that compared to 2012, we might expect that a $1 million expenditure in the year 2030 will support only 68 percent of the number of jobs as in 2012.[62]

Third, for purposes of estimating electricity bill savings, it was assumed that current electricity prices for the residential, commercial, and industrial sectors in the United States would follow the same growth rate as those published by the Energy Information Administration in its *Annual Energy Outlook* 2012.[63]

Fourth, it was assumed that the large-scale efficiency upgrades are financed by bank loans that carry an average 6 percent interest rate over a 5-year period. While this does raise the

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55. While this idea of scale more or less holds true, as costs begin to rise with a greater level of penetration of energy efficiency measures, the idea of diminishing returns could reduce overall cost-effectiveness of individual scenarios as a function of the total level of savings that might be achieve – in this case, for the year 2030. See generally the discussion on this point as highlighted by Table 6 that follows the main finding of this exploratory effort.
56. For a historical review of how this type of analysis is carried out, see Laitner, Bernow, and DeCicco (1998).
57. Bureau of Labor Statistics. 2012. Economic and Employment Projections 2010 to 2020. Washington, DC: U.S. Department of Labor. (Available at: http://www.bls.gov/news.release/ecopro.toc.htm).
58. The calculation is $1/(1.022)^{18} * 100$ equals $1/1.4796 * 100$, or 68 percent.
59. EIA 2012.

cost to end-users as a result of the interest that must be paid on bank loans, raising or lowering the interest rates in this analysis will not appreciably affect the results otherwise reported. Also, to limit the scope of the analysis, no parameters were established to account for any changes in interest rates as less capital-intensive technologies (i.e., efficiency investments) are substituted for conventional supply strategies, or in labor participation rates—all of which might affect overall spending patterns.

While the higher cost premiums associated with the energy efficiency investments might be expected to drive up the level of borrowing (in the short term), and therefore interest rates, this upward pressure would be offset to some degree by the investment avoided in new power plant capacity, exploratory well drilling, and new pipelines. Similarly, while an increase in demand for labor would tend to increase the overall level of wages (and thus lessen economic activity), the job benefits are small compared to the current level of unemployment or underemployment. Hence, the effect would be negligible.

Fifth, for the buildings and industrial sectors it was assumed that a program and marketing expenditure would be required to promote market penetration of the efficiency improvements. Based on other program reviews, this was set at 15 percent of the efficiency investment in the early years but declining to 5 percent of the much larger investments in the last year of the assessment.[64]

Finally, it should again be noted that, by design, this analysis does not account for the full effects of the efficiency investments since the savings beyond 2030 are not incorporated into the modeling assumptions. Nor does the analysis include other productivity benefits that are likely to stem from the efficiency investments. These can be substantial, especially in the industrial sector. Industrial investments that increase energy efficiency often advance other economic goals such as improved product quality, lower capital and operating costs, increased employee productivity, or capturing specialized product markets.[65] To the extent these "co-benefits" are realized in addition to the energy savings, the net economic impacts would be amplified beyond those reported here.

IV. Economic Impact of a Cost-Effective Energy Efficiency Scenario

The investment and savings data from the efficiency identified above (again reaching a 20 percent electricity savings through efficiency gains by 2020) were used to estimate the financial and the economy-wide impacts for the key benchmark years of 2014, 2020, 2025, and 2030. Each change in sector spending was evaluated by the Investment and Spending module within the DEEPER model for a given year—relative to the baseline or business-as-usual scenario. These were then matched to their appropriate sector impact coefficients.

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60. The assumption here is that program spending is necessary to encourage, monitor, and verify the requisite efficiency gains. In addition, training programs as well as increased research & development expenditures may also be needed to improve technology performance and market penetration. This range is generally consistent with the findings of Friedrich et al. (2009). For other examples that integrate program spending into efficiency policy assessments, see Laitner et al. (2010) among other studies.
61. For a more complete discussion on this point, see Elliott, Laitner, and Pye (1997) and Worrell et al. (2003).

These changes were further evaluated by DEEPER's macroeconomic module to estimate the larger overall job and wage benefits for the U.S. economy.

Starting with very small impacts in 2014, the end-use energy efficiency target of a 20 percent savings by 2030 spurs both program costs and technology investments that, in turn, begin to change the patterns of electricity consumption and production. Program spending of $635 million in 2014 is assumed to drive an initial $4,231 million in technology investments in that year. But these investments are assumed to be financed over time so that the actual outlays in 2014 are only $1,004 million. The initial impacts on electricity production are relatively small, reducing electricity bills by an estimated $2,834 million (about 0.8 percent of the reference case electricity expenditures otherwise projected in that year). However, both program spending and the annualized efficiency payments rise to 2.3 and 39.5 billion dollars by 2030, respectively.

Table 4. Key Annual Financial and Economic Impacts from the Efficiency Scenario

	2014	2020	2025	2030	Average 2014-2030
Financial Costs (Million 2010 $)					
Program Costs	635	843	1,532	2,259	1,229
Efficiency Investments	4,231	8,486	21,741	45,184	17,040
Annualized Efficiency Payments	1,004	8,258	18,956	39,533	8,053
Energy Bill Savings	2,834	23,785	52,451	87,977	26,703
Net Energy Bill Savings	1,196	14,683	31,963	46,185	17,420
Cumulative Net Energy Savings	1,196	50,714	175,883	381,146	381,146
Net Savings per Household (actual $)	6	62	121	147	84
Macroeconomic Impacts					
Employment (actual)	49,504	206,419	484,032	818,827	316,612
Percent from Reference Case	0.04%	0.14%	0.31%	0.51%	
Wages (Million 2010 $)	2,453	9,868	24,877	44,503	16,295
Percent from Reference Case	0.03%	0.10%	0.25%	0.42%	
GDP (Million 2010 $)	2,262	4,261	13,752	26,262	8,869
Percent from Reference Case	0.01%	0.03%	0.07%	0.12%	

Source: Analysis as described in the text of the working paper.

The net savings on electricity bills (i.e., the savings after program costs and the annual payments for investments have been paid) exceeds $46 billion (rounded) in 2030, which is about 11 percent of the nation's reference case electricity bill for that year. The net residential or household savings start at only $6 in 2014, slowly increasing to $62 in 2020, and then rise steadily to an annual $147 savings for an average household by 2030.

As might be expected, the program spending and changed investment patterns have a distinct economic impact. The second set of impacts in Table 4 highlights the key employment and wage benefits for the same years. Overall employment benefits begin with about 49,504 jobs in 2014, but grow steadily as both investments and electricity savings increase over time. By 2030, the total job gain reaches 818,827 jobs, about 0.51 percent of the jobs otherwise available in that year. Wages associated with the added jobs similarly increase to just short of $45 billion by 2030.

Table 5. Net Employment Impacts (Actual Jobs)

	2014	2020	2025	2030	Average 2014-2030
Overall Jobs Impacts	49,504	206,419	484,032	818,827	353,860

Source: Analysis as described in the text of the working paper.

We also ran a series of sensitivity simulations to test the robustness of the 20 percent savings target in 2030. Table 6, below, summarizes those findings. In effect, we compare the year 2030 savings target with the net savings (in millions of 2010 dollars) in that year, the average savings per household (in actual but still constant 2010 dollars) also in 2030, and finally, the overall job gain that might be created in that last year of the efficiency scenario. In addition, we provide a benefit-cost ratio that discounts the savings and the program and investment costs over the period 2014 through 2030 using a 5 percent discount rate.

Table 6. Net Benefits as a Function of Efficiency Target

2030 Target	BCR	Average/HH	Net Savings	Net Jobs
5%	4.2	72	18,217	169,112
10%	3.3	127	33,036	350,199
15%	2.6	157	43,194	563,013
20%	2.1	147	46,185	818,827
25%	1.7	73	38,089	1,145,333
30%	1.3	-101	12,986	1,590,403

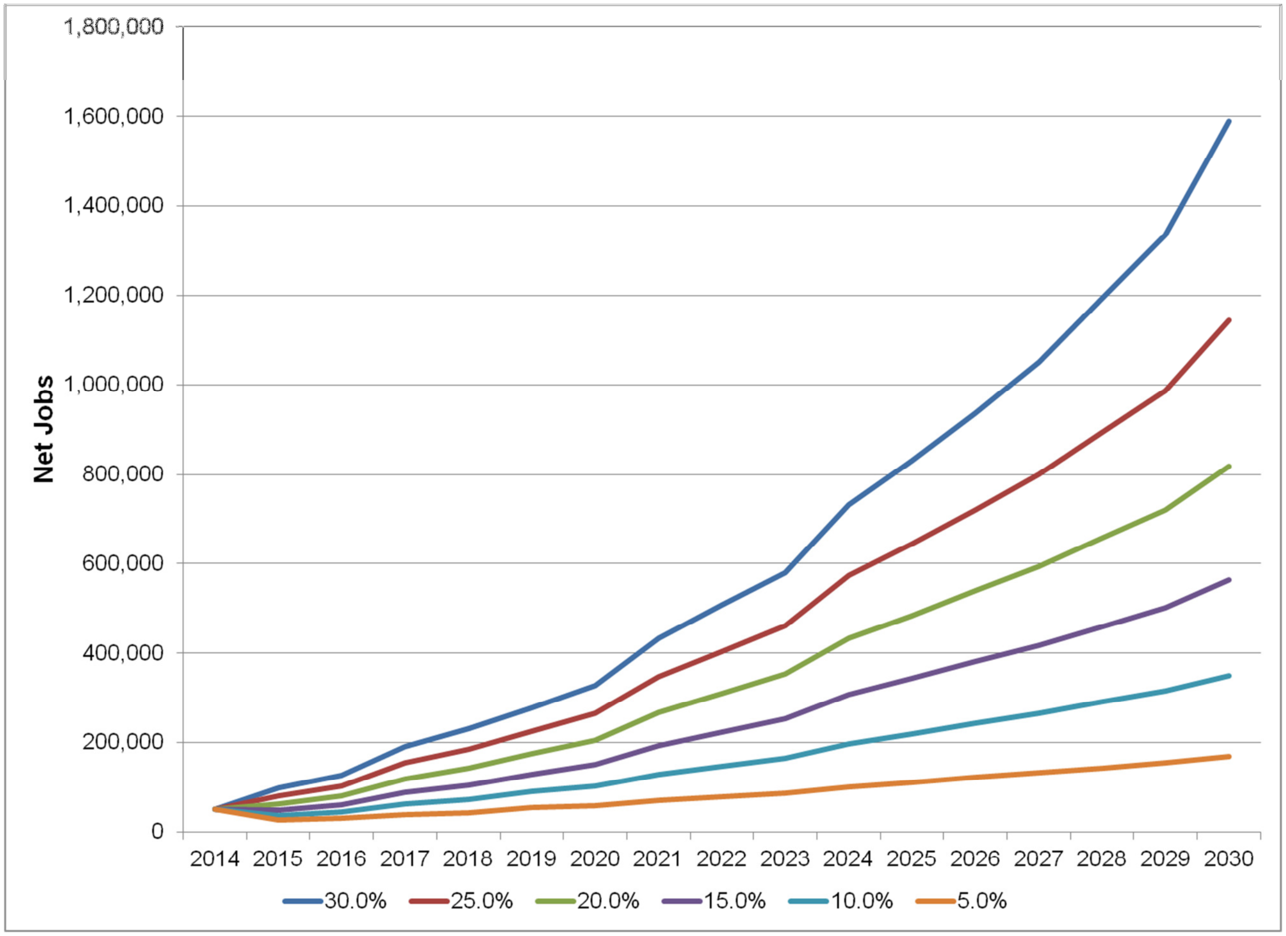
Source: Analysis as described in the text of the working paper.

Beginning with a 5 percent savings target, we find that the smallest effort shows the largest benefit-cost ratio (assuming all costs are discounted 5 percent annually). This makes sense as the least-cost resources are likely to be used up first. By themselves, however, the very cheapest efficiency resources do not generate sufficient savings to drive a very large gain in employment – in this case 169,112 jobs. The maximum net savings per household tops out at about 15 percent efficiency savings. That provides an average net return of $157 per household. At that level employment increases by about 563,013 jobs per year.

The maximum net energy bill savings is reached at about the 20 percent target with a net return of $46,185 million which helps drive the gain of 818,827 jobs as we described in the text surrounding tables 4 and 5. The least cost-effective scenario calls for a 30 percent savings target; although less cost-effective, this scenario also generates the greatest number of total jobs because of the substantial construction activity generated in the later years to achieve this level of savings.

Figure 4 provides a graphic summary of overall job impacts by year as a function of the year 2030 savings from the reference case. Beginning with the assumption that first year savings in 2014 is about 0.75 percent of reference case sales, each of the scenarios slowly increases the gain in jobs as greater investments drive a greater level of savings. The year 2030 end-points are consistent with the results presented in Table 6 on the previous page.

Figure 4. Net Job Impacts of Energy Efficiency Scenarios by Year 2030 Percent Savings



Source: Analysis as described in the text of the working paper.

Finally, and although not part of the DEEPER modeling system, we also provide a working estimate of the reduction in air pollution and greenhouse gas emissions in the year 2030 for the 20 percent savings scenario. This is roughly calculated as the difference in the year 2030 electricity generation in the BAU compared to the efficiency-led scenario multiplied by the 2030 (avoided) average rate of emissions (pounds per kWh) of sulfur dioxide, nitrogen oxides, and carbon dioxide emissions. The average rates of emissions in the 2030 efficiency-led scenario are further reduced by the 20 percent savings under the assumption that it is the marginal generation power plants (essentially the generally dirtier units) that will be displaced by the alternative pattern of investments guided by carbon pollution standards. Table 7 summarizes the reduced impacts of air pollution and greenhouse gas emissions.

Table 7. 20% Scenario Emissions Savings in 2030

	2030
Sulfur Dioxide (million short tons)	0.7
Nitrogen Oxides (million short tons)	0.8
Carbon Dioxide (million metric tons)	971

In short, mobilizing energy efficiency as a pollution reduction mechanism can provide dramatic reductions in air pollution and greenhouse gas emissions. Achieving a 20 percent improvement in efficiency by 2030 could reduce emissions of sulfur dioxide and nitrogen oxides by 700,000 and 800,000 tons, respectively, and cut carbon pollution by 971 million metric tons—nearly a full gigaton—even as consumers and businesses save money and new jobs are created. The emission reductions described in Table 7 are about 57 percent of the emissions projected in the power sector for the year 2030 in the business-as-usual case.

V. Conclusions

The evidence presented here documents the critical role that energy efficiency can play in positively shaping both our economy and our environment. If we choose to develop that resource as characterized in this working paper, a 20 percent electricity savings by the year 2030 can catalyze large net consumer savings as well as launch an important opportunity to stimulate greater job creation – even as we bring about a substantial reduction in carbon pollution and other harmful air pollutants.

Upcoming EPA rulemakings addressing carbon dioxide emissions from the power sector present a unparalleled opportunity to realize the massive economic and environmental benefits of energy efficiency. President Obama has directed the EPA to proceed with a rulemaking to establish limits on greenhouse gas emissions from existing power plants under section 111(d) of the Clean Air Act.[66] The language of section 111(d) is sufficiently broad to encompass a system-based approach to securing carbon pollution reductions from existing power plants.[67] A system-based approach could provide an excellent opportunity for EPA to consider end-use energy efficiency as a compliance mechanism through which the power sector can achieve meaningful, low-cost emission reductions.[68]

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62. *See* Sara Hayes and Garrett Herndon, *Trailblazing Without the Smog: Incorporating Energy Efficiency into Greenhouse Gas Limits for Existing Power Plants*, American Council for an Energy-Efficient Economy (2013).
63. *See* Megan Ceronsky and Tomás Carbonell, *Section 111(d) of the Clean Air Act: The Legal Foundation for Strong, Flexible & Cost-Effective Carbon Pollution Standards for Existing Power Plants*, Environmental Defense Fund (2013).
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Appendix A: An Overview of the Energy Efficiency Resource

I. What is Energy Efficiency?

All interactions of matter involve flows of energy. This is true whether they have to do with earthquakes, the movement of the planets, or the various biological and industrial processes at work anywhere in the world. Within the context of a regional or national economy, the assumption is that energy should be used as efficiently as technically and economically feasible. An industrial plant working two shifts a day six days a week for 50 weeks per year, for example, may require more than $1 million per year in purchased energy if it is to maintain operation. An average American household may spend $2,000 or more per year for electricity and natural gas to heat, cool, and light the home as well as to power all of the appliances and gadgets within the house. And an over-the-road trucker may spend $60,000 or more per year on fuel to haul freight an average of 100,000 miles. Regardless of either the scale or the kind of activity, a more energy-efficient operation might lower overall costs for the manufacturing plant, for the household, and for the trucker. The question is whether the annual energy bill savings are worth either the cost or the effort that might be necessary to become more energy-efficient.[69]

As it turns out the U.S. economy is not especially energy-efficient. At current levels of consumption the U.S. economy converts about 14 percent of all the energy consumed into useful work – which means we waste about 86 percent of the energy resources now expended to maintain our economy.[70] Because of that very significant level of inefficiency, many in both the business and the policy community increasingly look to energy efficiency improvements as cost-effective investments to improve efficiency and reduce waste.

The current system of generating and delivering electricity to homes and businesses in the United States is just 32 percent efficient. That is, for every three lumps of coal or other fuel used to generate power, the energy from only one lump is actually delivered to homes and businesses in the form of electricity. What America wastes in the generation of electricity is more than Japan needs to power its entire economy. The technologies that power the fossil-fuel economy, for example the internal combustion engine and steam turbines, are no more efficient today than they were in 1960, when President Eisenhower was in office.[71] Laitner (2013) suggests that this level of inefficiency may actually constrain the greater productivity of the economy.[72] And yet, any number of technologies can greatly improve energy performance. Combined heat and power (CHP) systems, for example, can deliver efficiencies of 65 to 80 percent or more, at a substantial economic savings.[73] And an incredible array of waste-to-

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65. The energy expenditures are derived from several calculations by the author.
66. Laitner 2013, building on Ayres and Warr 2009.
67. Ayres, Robert U. and Edward H. Ayres. 2010. *Crossing the Energy Divide: Moving from Fossil Fuel Dependence to a Clean-Energy Future.* Upper Saddle River, N.J.: Wharton School of Publishing.
68. Laitner 2013.
69. Chittum, Anna and Terry Sullivan. 2012. *Coal Retirements and the CHP Investment Opportunity*. ACEEE Report IE123. Washington, DC: American Council for an Energy-Efficient Economy.

energy and recycled energy technologies can further increase overall efficiency and save money.[74]

II. Historical Impact of Energy Efficiency

As one of the richest and more technologically advanced regions of the world, the United States has expanded its economic output by more than three-fold since 1970. Per capita incomes are also twice as large today compared to incomes in 1970. Notably, however, the demand for energy and power resources grew by only 40 percent during the same period.[75] This decoupling of economic growth and energy consumption is a function of increased energy productivity: in effect, the ability to generate greater economic output (that is, more goods and services), but to do so with less energy. Because these past gains were achieved with an often ad hoc approach to energy efficiency improvements, there is compelling evidence to suggest that even greater energy productivity benefits can be achieved. Indeed, the evidence suggests that since 1970, energy efficiency in its many different forms has met three-fourths of the new demands for energy-related goods and services while new energy supplies have provided only one-fourth of the new energy-related demands.[76] But energy efficiency has been an invisible resource. Unlike a new power plant or a new oil well, we don't see energy efficiency at work. A new car that gets 25 miles per gallon, for example, may not seem all that much different than a car that gets 40 miles or more per gallon. And yet, the first car will consume 400 gallons of gasoline to go 10,000 miles in a single year while the second car will need only 250 gallons per year.[77] In effect, energy efficiency in this example is the energy we don't use to travel 10,000 miles per year. More broadly, energy efficiency may be thought of as the cost-effective investments in the energy we don't use either to produce or even increase the level of goods and services within the economy.

III. The Cost-Effective Potential for the Energy Efficiency Resource

Can the substantial investments that might be required to obtain more energy-efficient technologies save money for businesses and consumers? Here we turn to the evidence to provide different views of this question. The Lazard Asset Management firm (2013) provides a

70. Bailey, Owen and Ernst Worrell. 2005. Clean Energy Technologies A Preliminary Inventory of the Potential for Electricity Generation. LBNL-57451. Berkeley, CA: Lawrence Berkeley National Laboratory.
71. These and other economic and energy-related data cited are the author's calculations as they are drawn from various resources available from the Energy Information Administration (2013a and 2013b).
72. Laitner 2013.
77. In August 2012 the Department of Transportation and the Environmental Protection Agency finalized federal car and light truck fuel economy and greenhouse gas emissions standards for model years 2017 to 2025. The standards, together with those previously adopted for model years 2012 to 2016, mean an 80 percent increase to more than 50 miles per gallon for the average model year 2025 vehicle from the 2011 CAFE (Corporate Average Fuel Economy) requirement of 27.6 miles per gallon (Langer 2012). A separate study by the BlueGreen Alliance and the American Council for an Energy-Efficient Economy determined that the new 2025 fuel economy standards would be cost-effective and produce a gain of 576,000 jobs (Busch et al. 2012). The jobs provided by the new fuel economy standards are at the same scale as the jobs that likely would provided by energy efficiency improvements in the use of electricity as suggested in the text of the main report.

detailed review of the various costs associated with electricity generation expenditures.[78] They note, for instance, that new coal and nuclear power plants might cost an average of 8 to 14 cents per kilowatt-hour (kWh) of electricity. The costs for various renewable energy resources such as wind energy or photovoltaic energy systems (i.e., solar cells that convert sunlight directly into electricity) range from 6 to 20 cents per kWh. And both Lazard (2013) and the American Council for an Energy-Efficient Economy (ACEEE) estimate a range of energy efficiency measures that might cost the equivalent of 3 to 5 cents per kWh of electricity service demands.[79] McKinsey & Company (2007) assessed the energy efficiency resource as having at least a 10 percent return on energy efficiency investments.[80] When spread out over an annual $170 billion energy efficiency market potential, McKinsey suggests an average 17 percent return might be expected across that spread of annual investments.[81] A subsequent study suggests that through 2020 there is sufficient cost-effective opportunity to reduce our nation's energy use by more than 20 percent – if we choose to invest in the more efficient use of our energy resources.[82]

Similarly, the AEC (1991) and the Energy Innovations (1997) reports show a benefit-cost ratio that also approached two to one.[83] More recently, the Union of Concerned Scientists published a detailed portfolio of technology and program options that would lower U.S. heat-trapping greenhouse gas emissions 56 percent below 2005 levels in 2030.[84] The result of their analysis indicated an annual $414 billion savings for U.S. households, vehicle owners, businesses, and industries by 2030. After subtracting the annual $160 billion costs (constant 2006 dollars) of the various policy and technology options, the net savings are on the order of $255 billion per year. Over the entire 2010 through 2030 study period, the net cumulative savings to consumers and businesses were calculated to be on the order of $1.7 trillion under their so-called Blueprint case.

Most recently, Laitner et al. (2012) documented an array of untapped cost-effective energy efficiency resources roughly equivalent to 250 billion barrels of oil.[85] That is a scale sufficient to enable the U.S. to reduce total energy needs by about one-half compared to standard reference case projections for the year 2050. These productivity gains could generate from 1.3

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74. Lazard, 2013. Lazard, Ltd. "Levelized Cost of Energy Analysis – Version 7.0." September, 2013.
75. *Id.*; Elliott, R. Neal, Rachel Gold, and Sara Hayes. 2011. Avoiding a Train Wreck: Replacing Old Coal Plants with Energy Efficiency. ACEEE White Paper. Washington, DC: American Council for an Energy-Efficient Economy.
76. McKinsey. 2007. *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?* The Conference Board and McKinsey & Company.
77. *Id.*
78. McKinsey. 2009. *Unlocking Energy Efficiency in the U.S. Economy*. McKinsey & Company.
79. Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, Union of Concerned Scientists, and Tellus Institute. 1991. *America's Energy Choices: Investing in a Strong Economy and a Clean Environment*. Cambridge, MA: Union of Concerned Scientists; Energy Innovations. 1997. *Energy Innovations: A Prosperous Path to a Clean Environment*. Washington, DC: Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, Tellus Institute, and Union of Concerned Scientists.
80. Cleetus Rachel, Stephen Clemmer, and David Friedman. 2009. *Climate 2030: A National Blueprint for a Clean Energy Economy*. Cambridge, MA: Union of Concerned Scientists.
81. Laitner, John A. "Skip," Steven Nadel, Harvey Sachs, R. Neal Elliott, and Siddiq Khan. 2012 *The Long-Term Energy Efficiency Potential: What the Evidence Suggests*, ACEEE Research Report E104, Washington, DC: American Council for an Energy-Efficient Economy. 2012.

to 1.9 million jobs while saving all residential and business consumers a net $400 billion per year, or the equivalent of about $2,600 per household annually (in 2010 dollars). Indeed, in *World Energy Outlook 2012*, the International Energy Agency (IEA 2012) highlighted the potential for energy efficiency to save 18 percent of the 2010 global energy consumption by 2035. More critically, the IEA notes that Global GDP would be 0.4 percent higher in 2035 as a result of those efficiency improvements.

There are two final aspects of the evidence to briefly review. The first is associated with the non-energy benefits that typically result from energy efficiency investments. The second reflects the changes one might normally expect in the cost and performance of technologies over time.

When energy efficiency measures are implemented in industrial, commercial, or residential settings, several "non-energy" benefits such as maintenance cost savings and revenue increases from greater production can often result in addition to the anticipated energy savings. The magnitude of non-energy benefits from energy efficiency measures is significant. These added savings or productivity gains range from reduced maintenance costs and lower waste of both water and chemicals to increased product yield and greater product quality. In one study of 52 industrial efficiency upgrades, all undertaken in separate industrial facilities, Worrell et al. (2003) found that these non-energy benefits were sufficiently large that they lowered the aggregate simple payback for energy efficiency projects from 4.2 years to 1.9 years.[86] Unfortunately, these non-energy benefits from energy efficiency measures are often omitted from conventional performance metrics. This leads, in turn, to overly modest payback calculations and an imperfect understanding of the full impact of additional efficiency investments.

Several other studies have quantified non-energy benefits from energy efficiency measures and numerous others have reported linkages from non-energy benefits and completed energy efficiency projects. In one, the simple payback from energy savings alone for 81 separate industrial energy efficiency projects was less than 2 years, indicating annual returns higher than 50 percent. When non-energy benefits were factored into the analysis, the simple payback fell to just under one year.[87] In residential buildings, non-energy benefits have been estimated to represent between 10 to 50 percent of household energy savings.[88] If the additional benefits from energy efficiency measures were captured in conventional performance models, such figures would make them more compelling. Building on that perspective, a new assessment by the Regulatory Assistance Project suggests there is, in fact, a “layer cake of benefits from electric energy efficiency”.[89] The layers or array of benefits falls

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82. Worrell, Ernst, John A. Laitner, Michael Ruth, and Hodayah Finman. 2003. "Productivity Benefits of Industrial Energy Efficiency Measures." *Energy* (2003), 28, 1081-98.
83. Lung, Robert Bruce, Aimee McKane, Robert Leach, Donald Marsh. 2005. “Ancillary Benefits and Production Benefits in the Evaluation of Industrial Energy Efficiency Measures.” *Proceedings of the 2005 Summer Study on Energy Efficiency in Industry*. Washington, DC: American Council for an Energy-Efficient Economy.
84. Amann, Jennifer. 2006. *Valuation of Non-Energy Benefits to Determine Cost-Effectiveness of Whole House Retrofit Programs: A Literature Review.* ACEEE Report A061. Washington, DC: American Council for an Energy-Efficient Economy.
85. Lazar, Jim and Ken Colburn. 2013. Recognizing the Full Value of Energy Efficiency. Montpelier, VT: Regulatory Assistance Project, at 10.

into three categories: utility system benefits, participant benefits, and societal benefits – each with six different types of positive returns. Using information provided by Efficiency Vermont as one example, Lazar and Colburn found that the mix of energy efficiency benefits typically included in utility revenue requirements approach 7-8 cents/kWh, but the full set of efficiency benefits could be as high as 18 cents/kWh.[90] Laitner et al. (2013) suggest that new business models are needed to fully capture the complete array of benefits.[91]

As a strong complement to the likelihood of large-scale non-energy benefits typically omitted from most climate policy assessments, there is also a significant body of evidence that indicates that technology is hardly static and non-dynamic. The rapid technological change seen especially in semiconductor-enabled technologies has led to cheaper, higher performing, and more energy-efficient technologies.[92] The increasing penetration of information and communication technologies interacting with energy-related behaviors and products suggests that energy efficiency resources may become progressively cheaper and more dynamic through the 21st century.[93] Given this and many other comparable studies, one might safely conclude that progress in the cost and performance of energy efficient technologies will continue, and that new public policies will greatly increase the continued rate of improvement.[94]

We can extend the issue of cost effectiveness even further to examine policy scenarios rather than discrete technologies. Laitner and McKinney (2008) provided a meta-review of 48 past policy studies that were undertaken primarily at the state or regional level.[95] The set of studies included in this assessment generally examined the costs of economy-wide efficiency investments made over a 15 to 25 year time horizon. The analysis found that even when both

86. In many ways the landmark volume, *Small Is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size*, by Lovins et al. (2002) underscores the many benefits which are mostly excluded from marketplace transactions. From the Small Is Profitable website: The report describes 207 ways "in which the size of 'electrical resources' – devices that make, save, or story electricity – affects their economic value. It finds that properly considering the economic benefits of 'distributed' (decentralized electrical resources typically raises their value by a large factor, often approximately tenfold, by improving system planning, utility construction and operation, and service quality, and by avoiding societal costs." *See*, http://www.smallisprofitable.org/.
87. Laitner, John A. "Skip," Matthew T. McDonnell and Heidi M. Keller. 2013. "Shifting Demand: From the Economic Imperative of Energy Efficiency to Business Models that Engage and Empower Consumers." In *End of Electricity Demand Growth: How Energy Efficiently Can Bring an End to the Need for More Power Plants*, Fereidoon P. Sioshansi (editor), Elsevier, 2013.
88. Laitner, John A. "Skip", Christopher Poland Knight, Vanessa McKinney, and Karen Ehrhardt-Martinez. 2009. *Semiconductor Technologies: The Potential to Revolutionize U.S. Energy Productivity.* Washington, DC: American Council for an Energy-Efficient Economy.
89. Laitner, John A. "Skip" and Karen Ehrhardt-Martinez. 2008. *Information and Communication Technologies: The Power of Productivity; How ICT Sectors Are Transforming the Economy While Driving Gains in Energy Productivity.* Washington, DC: American Council for an Energy-Efficient Economy.
90. McKinsey. 2009. *Unlocking Energy Efficiency in the U.S. Economy*. McKinsey & Company; Koomey, Jonathan. 2008. "Testimony of Jonathan Koomey, Ph.D. Before the Joint Economic Committee of the United States Congress," For a hearing on Efficiency: The Hidden Secret to Solving Our Energy Crisis." Washington, DC: Joint Economic Committee of the United States Congress. June 30, 2008.
91. Laitner, John A. "Skip" and Vanessa McKinney. 2008. *Positive Returns: State Energy Efficiency Analyses Can Inform U.S. Energy Policy Assessments*. ACEEE Report E084. Washington, DC: American Council for an Energy-Efficient Economy.

program costs and technology investments were compared, the savings appeared to be twice the cost of the suggested policies.

IV. Overcoming Barriers to Improving Energy Efficiency

Although some economists have questioned the magnitude of the energy efficiency resource, close examination of the evidence indicates that the resource is in fact vast. Allcott and Greenstone (2012), for example, suggest that “recent empirical work in a variety of contexts implies that on average the magnitude of profitable unexploited investment opportunities is much smaller than engineering-accounting studies suggest.”[96] In effect, they pose the central economic question, “Is there an Energy Efficiency Gap?” In other words, is energy efficiency a sufficiently large, cost-effective resource that can be relied upon as a meaningful energy policy option?(Allcott and Greenstone 2012). In fact, the issue was rigorously explored as early as 1995. Levine et al. (1995), for example, examined this issue in a significant journal article, “Energy Efficiency Policy and Market Failures.”[97] After a careful review they concluded, “[w]e believe that energy efficiency policies aimed at improving energy efficiency at a lower cost than society currently pays for energy services represent good public policy. Programs that lead to increased economic efficiency as well as energy efficiency should continue to be pursued.” More recently, Nadel and Langer (2012), in a thoughtful review of Allcott and Greenstone, suggest that “while the authors have some useful points to make, in general they interpret available data in ways that best support their points, downplaying other important findings in the various articles they cite.”[98] Nadel and Langer argue that a fuller consideration of the evidence shows that there is in fact a large, cost-effective energy efficiency resource available to be harvested.

Another relevant area of inquiry examines why cost-effective efficiency opportunities remain unexploited given the cost-savings potential. There is a range of market imperfections, market barriers, and real world behaviors that leaves substantial room for public policy to induce behavioral changes that produce economic benefits. One classic example is the misaligned incentive that exists for those living in rental units when the renter pays the energy bills but the landlord purchases large energy-using appliances such as refrigerators and water heaters. In this case, the purchaser of the durable good does not reap the benefits of greater energy efficiency and has no incentive to select highly efficient appliances. The Market Advisory Committee of the California Air Resources Board (2007) provides a short overview of this and other key market failures.[99, 100] A deeper exploration of the types of market barriers is beyond

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92. Allcott Hunt and Michael Greenstone. 2012. “ Is There an Energy Efficiency Gap?” *Journal of Economic Perspectives* 26 (1) : 3-28
93. Levine, Mark D. Jonathan G. Koomey, James E. McMahon, Alan H. Sanstad, and Eric Hirst. 1995, "Energy Efficiency Policy and Market Failures." Annual Review of Energy and the Environment 20: 535-555.
94. Nadel, Steven and Therese Langer. 2012. Comments on the July 2012 Revision of “Is There an Energy Efficiency Gap?” ACEEE White Paper. Washington, DC: American Council for an Energy-Efficient Economy.
95. California Air Resources Board. 2007. Recommendations for Designing a Greenhouse Gas Cap-and-Trade System for California. http://www.energy.ca.gov/2007publications/ARB-1000-2007-007/ARB-1000-2007-007.PDF. Sacramento, Calif.: California Air Resources Board, Market Advisory Committee.
96. Following are examples of important market failures: (1) Step-Change Technology Development—where temporary incentives will be needed to encourage companies to deploy new technologies at large scale to the public good, because there is otherwise excessive technology, market, and policy risk. Examples of remedies are

the scope of this working paper, but others have done work to map this terrain.[101] A flexible framework to reduce greenhouse gas emissions from existing fossil fuel power plants that empowers states and companies to invest in energy efficiency to reduce pollution would provide an important opportunity to eliminate these barriers.

One important implication of the literature on market imperfections and energy efficiency is that price signals alone may not drive optimal levels of energy efficiency investment. This concept was explored by Hanson and Laitner (2004).[102] In one of the few top-down models that explicitly reflects both policies and behavioral changes as a complement to pricing signals, this study found that the combination of both price and non-pricing policies actually resulted in a significantly greater level of energy efficiency gains and a lower carbon allowance price to achieve the same level of emissions reductions, thereby achieving an overall reduction in the costs of achieving those reductions.

Appendix B: Methodology of the DEEPER Modeling System

To evaluate the macroeconomic impacts of reductions in fossil fuel fired plant emissions from demand-side efficiency improvements, we use the proprietary **D**ynamic **E**nergy **E**fficiency **P**olicy **E**valuation **R**outine, or DEEPER model. The model was developed by John A. "Skip" Laitner and has a 22-year history of use and development, though it was renamed "DEEPER" in 2007. It was most recently used in a study for the BlueGreen Alliance and the American Council for an Energy-Efficient Economy (ACEEE) evaluating the overall job impacts of the recently enacted fuel economy standards.[103]

The DEEPER Modeling System is a quasi-dynamic input-output (I/O) model[104] of the U.S. economy that draws upon social accounting matrices[105] from the MIG, Inc. (formerly the Minnesota IMPLAN Group),[106] energy use data from the U.S. Energy Information Administration's Annual Energy Outlook (AEO), and employment and labor data from the

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renewable portfolio obligations, biofuel requirements, and California's Low Carbon Fuel Standard. (2) Fragmented supply chains—where economically rational investments (for example, energy efficiency in buildings) are not executed because of the complex supply chain. Examples of remedies are building codes. (3) Consumer behavior—where individuals have demonstrated high discount rates for investment in energy efficiency that is inconsistent with the public good. Examples of remedies are vehicle and appliance efficiency standards and rebate programs (California Air Resources Board 2007, p.19).

97. See, for example, Levine et al. 1995 previously referenced, but also Brown (2001); Levinson and Niemann (2004); Sathaye and Murtishaw (2004); Murtishaw and Sathaye (2006); Geller et al. (2006); Brown et al. (2009).

98. Hanson, Donald A. and John A. "Skip" Laitner. 2004. "An Integrated Analysis of Policies that Increase Investments in Advanced Energy-Efficient/Low-Carbon Technologies." *Energy Economics* 26:739-755.

99. Busch, Chris, John Laitner, Rob McCulloch, Ivana Stosic. 2012. *Gearing Up: Smart Standards Create Good Jobs Building Cleaner Cars.* Washington, DC: BlueGreen Alliance and the American Council for an Energy-Efficient Economy (Available at: http://www.bluegreenalliance.org/news/publications/gearing-up).

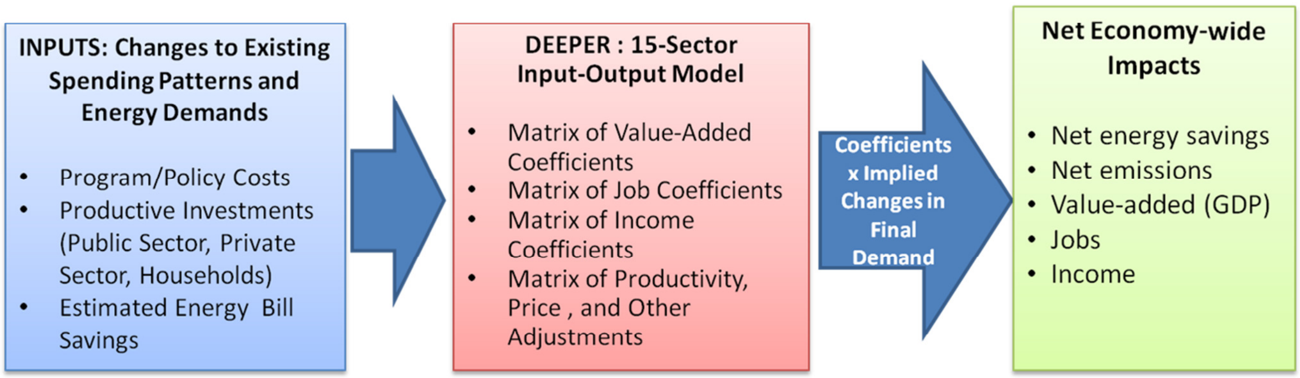
101. Input-output models use economic data to study the relationships among producers, suppliers, and consumers. They are often used to show how interactions among all three impact the macroeconomy.

102. A social accounting matrix is a data framework for an economy that represents how different institutions — households, industries, businesses, and governments — all trade goods and services with one another.

103. See http://implan.com/V4/Index.php.

Bureau of Labor Statistics (BLS). The Excel-based tool contains approximately eight interdependent worksheets. The model functions as laid out in the flow diagram below:

The DEEPER Modeling System



DEEPER results are driven by adjustments to energy service demands and alternative investment patterns resulting from projected changes in policies and prices between baseline and policy scenarios. The model is capable of evaluating policies at the national level through 2050. However, given uncertainty surrounding future economic conditions and the life of the impacts resulting from the policies analyzed, it is often used to evaluate out 15–20 years. Although the DEEPER Model, like most I/O models, is not a general equilibrium model,[107] it does provide accounting detail that balances changes in investments and expenditures within the economy. With consideration for goods or services that are imported, it balances the variety of changes across all sectors of the economy.[108]

The Macroeconomic Module contains the factors of production — including capital (or investment), labor, and energy resources — that drive the U.S. economy for a given "base year." DEEPER uses a set of economic accounts that specify how different sectors of the economy buy (purchase inputs) from and sell (deliver outputs) to each other.[109]

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

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104. General equilibrium models operate on the assumption that a set of prices exists for an economy to ensure that supply and demand are in an overall equilibrium.
105. When both equilibrium and dynamic input-output models use the same technology assumptions, both models should generate a reasonably comparable set of outcomes. See Hanson and Laitner (2005) for a diagnostic assessment that reached that conclusion.
106. Further details on this set of linkages can be found in Hanson and Laitner (2009).

The resulting positive and negative changes in spending and investments in each year are converted into sector-specific changes in aggregate demand.[110] These results then drive the I/O matrices utilizing a predictive algebraic expression known as the Leontief Inverse Matrix.[111]

Employment quantities are adjusted annually according to assumptions about the anticipated labor productivity improvements based on forecasts from the Bureau of Labor Statistics. The DEEPER Macroeconomic Module traces how changes in spending will ripple through the U.S. economy in each year of the assessment period. The end result is a net change between the reference and policy scenarios in jobs, income, and value-added,[112] which is typically measured as Gross Domestic Product (GDP) or value-added Gross Regional Product (GRP) for the study region (e.g., the national, state, or local economies).

Like all economic models, DEEPER has strengths and weaknesses. It is robust by comparison to some I/O models because it can account for price and quantity changes over time and is sensitive to shifts in investment flows. It also reflects sector-specific labor intensities across the U.S economy. However, it is important to remember when interpreting results for the DEEPER model that the results rely heavily on the quality of the information that is provided and the modeler's own assumptions and judgment. The results are unique to the specified policy design. The results reflect differences between scenarios in a future year, and like any prediction of the future, they are subject to uncertainty.

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109. This is the total demand for final goods and services in the economy at a given time and price level.
110. For a more complete discussion of these concepts, see Miller and Blair (2009).
111. This is the market value of all final goods and services produced within a country in a given period.

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