Clean Energy Partnerships: A Decade of Success

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Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy
Washington, DC 20585

FOREWORD

The Office of Energy Efficiency and Renewable Energy (EERE) manages a portfolio of research, technology development, demonstration, deployment, and project activities that supports the U.S. Department of Energy's strategic objectives. The results of these programs are dramatic – from a more efficient industrial base to a growing clean energy technology industry; from tremendous energy savings in homes, offices and government buildings to fleets of vehicles powered by domestically produced alternatives to imported petroleum fuels.

In this publication we have gathered some examples of recent accomplishments of EERE programs so stakeholders can see the value they are receiving from their investments. These are stories of positive impacts on real people and places that can be linked to DOE-sponsored activities, and have both quantitative and tangible benefits. While they do not comprise a comprehensive compendium of achievements, they do illustrate the range and diversity of successful EERE programs.

This report provides an analysis of program impacts giving credible evidence of positive returns on investment for a selection of accomplishments from the 1990s. This effort followed standard quality assurance techniques and included reviews by objective experts outside of DOE who are familiar both with EERE technologies and with evaluation techniques. These experts reviewed drafts of these success stories and also examined accompanying documentation.

I want to thank all of the EERE program managers and headquarters and regional staff who made these stories possible. Thanks are especially due to Eric Petersen and Darrell Beschen for initiating this effort. The passing of Eric in August 1999 was a terrible loss. He was a valued contributor to EERE's programs and a personal friend. He will be sorely missed. I would also like to recognize the contributions made by a multi-laboratory team comprised of Marilyn Brown and John Munro from Oak Ridge National Laboratory, Gretchen Jordan of Sandia National Laboratories, and John Mortensen of the National Renewable Energy Laboratory.

Finally, our success depends on the commitment and ingenuity of numerous DOE program managers and staff, National Laboratory scientists and engineers, and collaborators and partners in industry, non-governmental agencies, universities, utilities, state and local governments, and other government agencies. I believe we can all be proud of and share in the credit for the success stories presented in this publication. I look forward to future successes on behalf of the nation.

Dan W. Reicher
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Energy Efficiency and Renewable Energy

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EXECUTIVE SUMMARY

This report contains a partial catalog of recent accomplishments of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) in collaboration with its many private- and public-sector partners. This compendium of success stories illustrates the range and diversity of EERE programs and achievements. Part of an ongoing effort, the principal goal of this collection is to provide stakeholders with the evidence they need to assess the value they are receiving from investments in these DOE programs. The report begins with an introduction and a description of the methodology. It then presents an overview of the accomplishments of EERE programs. This is followed by the stories themselves.

Twenty accomplishments are included in the summary analysis of quantified benefits for EERE-supported products and technologies installed to date. The metrics compiled for these successes are up-to-date through Fiscal Year 1999. The approach to calculating benefits and costs is detailed in Appendix A.

EERE invested $712 million in the projects described in the 20 stories. Additional costs have been incurred by the numerous industrial, university, utility, and public-sector collaborators that have also invested in the commercialization and deployment of these technologies.

More than 5,500 trillion Btu of energy has been saved from equipment implemented to date as a result of these 20 activities. Of this total, 5,050 trillion Btu of savings is from EERE R&D successes, and almost 500 trillion Btu is from EERE field verification, deployment, and outreach successes. These savings are enough to meet the energy needs of all of the citizens, businesses, and industries located in the states of New York, Connecticut, and New Mexico, for one year. In addition, the 20 EERE R&D and field verification, deployment, and outreach programs have replaced another 1,700 trillion Btu of fossil fuels with renewable alternatives. This is equivalent to running all of the cars registered in the states of California, Florida, Mississippi, and West Virginia on ethanol rather than gasoline, for one year. Significant reductions in carbon emissions from these 20 activities, 102 million metric tons, have resulted from these reductions in burning fossil fuels.

As an order of magnitude estimate, **savings to the nation from these 20 activities are estimated to be $30 billion ($1998).** This is based on the 5,500 trillion Btu of energy savings and the cost to consumers of an average Btu of energy consumed in 1998. In 1996, the General Accounting Office reviewed the success of five similarly situated technologies developed in the 1980s, and found a cumulative energy savings from all installations through 1996 to be $28 billion, or over $3 billion per year.

These benefits will continue to accumulate and grow as many of the technologies that have been commercialized with the support of EERE resources gain market share over the next several years. Compact fluorescent torchieres, spectrally selective glazings for windows, and lightweight materials for vehicles are examples of commercial products that are likely to produce much greater energy saving over the next decade than they have produced to date.

A sample of seven of the emerging technologies hold the promise of additional billions of dollars in energy savings, from a DOE R&D investment in the 1990s of $288 million. $6 billion could be saved annually if all refrigerators used as little power as DOE's recently-developed high-efficiency refrigerators. The use of nickel aluminides could save industry $180 million, and another $160 million in cost savings could come from the installation of combined heat and power systems. The application of high temperature superconductivity to reduce losses from the transmission and distribution of electricity could save more than $550 million by 2010. Lost foam metal casting, improvements to the manufacture of thin film photovoltaics, and the use of biomass gasifiers and other EERE accomplishments will also reduce energy costs in the future.

INTRODUCTION AND OVERVIEW OF BENEFITS

INTRODUCTION

This report presents a number of stories of recent technology breakthroughs and program achievements of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE). These documented accomplishments will allow stakeholders to assess the value they are receiving from investments in these DOE programs. This report is not a complete compendium of EERE's successes; resource limitations prevent an exhaustive cataloging of all of the positive outcomes of EERE's activities. However, this overview does illustrate the range and diversity of EERE programs and achievements.

The objective of this report is to measure, evaluate, and articulate EERE's successes at a corporate level based on quantitative benefits and costs, using methods that withstand critical review. The accomplishments documented here demonstrate that the activities of EERE's research and development (R&D) and field verification, deployment, and outreach programs have resulted in significant energy savings, reduced energy costs, and decreased carbon emissions – key metrics by which EERE judges its success.

This document begins with an overview of the methodology used to select and document recent accomplishments. The remaining sections describe benefits and individual recent successes in two categories:

- R&D successes resulting in commercialized technologies that are successfully competing in the marketplace, and
- field verification, deployment, and outreach successes that have accelerated and expanded the use of existing efficient and renewable energy technologies.

An Afterword presents additional successes that document the numerous DOE-funded technologies in the pipeline for future commercialization, field verification, and deployment opportunities. Appendices A and B provide detail on the calculations in the stories and a glossary for readers unfamiliar with the terms and abbreviations used in this report.

BACKGROUND

The EERE mission is to lead the nation in the research, development, and deployment of advanced energy efficiency and clean power technologies and practices, providing Americans with a stronger economy, healthier environment, and more secure future. EERE's mission is consistent with the federal government's role of investing in technologies and practices that are critical to the nation's strategic interests, but that do not receive adequate research and development investment from the private sector. EERE also works with stakeholders to develop policies and programs to facilitate the deployment of advanced clean energy technologies and practices.

This approach enables EERE programs to advance America's existing energy systems by:

- Helping ensure adequate, affordable supplies of clean energy,
- Reducing U.S. vulnerability to energy supply disruptions,
- Encouraging energy efficiency,
- Advancing renewable energy and natural gas technologies,
- Increasing energy choices for all consumers, and

· Reducing the environmental impact of energy use.

EERE is committed to following best business practices, which involve effective performance measurement and refinement of program strategies as new information is obtained. This document is a product of that commitment to evaluation and continuous improvement.

METHODOLOGY

A careful selection process was used to arrive at an illustrative set of projects to be included in this publication. The first step was to generate a list of candidate accomplishments. These candidates were then mapped against the budget structure and program areas for EERE so an array of different programs would be included. The other criteria that guided the selection process were: significant breakthroughs or impacts since 1990; clear linkage between DOE expenditures and impacts; quantifiable, measured, and tangible benefits; documentation of DOE expenditures; and willingness by success story participants to provide additional data. Some of the data in the accomplishment stories are drawn from published sources. In other instances the multi-laboratory team[1] collected and compiled data through discussions with DOE program managers, national laboratory staff, and others involved with the projects.

A summary analysis is based on 20 accomplishments (11 R&D successes and nine field verification, deployment, and outreach successes), for which quantified benefits could be measured for products and technologies installed to date. Data on estimated future benefits for emerging R&D successes were also collected.

The accomplishments detailed in this compilation were drawn from an array of different sources and describe a variety of program activities. The approach taken and the assumptions made in the calculation of benefits and costs differ across stories. Therefore, we have made no attempt to aggregate costs and benefits of the success stories.

As a means of external validation and quality control, the accomplishments and their supporting documentation were reviewed by experts from government, universities and the private sector who are familiar with the technologies and with program evaluation techniques. The assumptions in each success story were reviewed for conformity with accepted evaluation methodologies. Limited resources, however, did not permit extensive recalculations based on standardized assumptions.

RESEARCH AND DEVELOPMENT SUCCESSES

Some Recent Accomplishments

The following accomplishment stories describe new technologies that were spawned by EERE's R&D programs and that are currently contributing to U.S. energy, environmental, and economic strategic interests (Box 1). These technologies increase the efficiency of energy use in buildings, industry, and transportation and advance the development of renewable energy resources. The R&D teams range from individual inventors to industrial consortia, and often involve researchers and the facilities of DOE's National Laboratories. More detail on the level of DOE R&D investment and the actual benefits from the R&D successes showcased in this report is available in Appendix A.

[1] The multi-laboratory team consisted of Oak Ridge National Laboratory, Sandia National Laboratories, and the National Renewable Energy Laboratory.

Box 1: Eleven R&D Successes

- Hazardous, energy-intensive halogen torchieres are being replaced by safe and efficient **compact-fluorescent torchieres** developed by Lawrence Berkeley National Laboratory in collaboration with lighting industry partners. Energy cost savings from the sale of the 200,000 compact fluorescent bulbs sold in 1998 will be $41 million over the 7-year life of the bulbs.
- DOE's leadership and research in collaboration with industry, Oak Ridge National Laboratory, and the National Institute of Standards and Technology accelerated the development of **ozone-safe refrigerants** by an estimated two years and averted a $16 billion energy penalty.
- **Spectrally selective glazings** developed by Lawrence Berkeley National Laboratory in collaboration with manufacturers and the National Fenestration Rating Council can cut cooling costs by 10-25% in hot climates. These cuts in cooling costs could result in savings of $1.3 billion per year from lowered electricity bills by 2010.
- Working with industrial partners the Office of Industrial Technologies funded R&D on **oxygen-fueled glass furnace technologies**, technologies used to manufacture 30 percent of all glass in 1999. Cumulative energy savings through 1997 totaled $28 million, with over $7 million in energy costs being saved annually by U.S. manufacturers.
- The **Inventions and Innovations Program** has provided small grants to more than 500 inventors; 25% of these grantees have produced commercialized technologies, and the sales of these products exceed $700 million ($1995) through 1996. Energy cost savings attributable to these grant-funded inventions were over $190 million.
- DOE's efforts to develop **lightweight materials** for manufacturing auto parts have saved more than 6 billion gallons of motor fuel and reduced carbon emissions by approximately 15 million metric tons through 1997. The dollars saved in oil-based fuels over the period from 1978 to 1997 is estimated at about $7 billion.
- DOE, in cooperation with industry partners, has developed **diesel engine technologies** that are both cleaner and more energy efficient, saving approximately 16 billion gallons of motor fuel and reducing carbon emissions by about 38 million metric tons through 1997. The cumulative economic value of increased efficiency is estimated at about $17 billion.
- Improvements in parabolic trough technology have reduced the O&M costs of **parabolic trough plants** by 30%, saving $4 million per year and $42 million over the lifetime of the trough. These improvements have also increased the performance of the world's largest solar plant to record levels.
- DOE's research partnerships with U.S. industry have led to **wind turbine advances** that are helping the United States be a leader in technology for the world's fastest growing energy source. Over their lifetimes turbines produced and installed by just one U.S. company will displace 110 trillion Btu of primary energy, save $246 million in energy costs, and reduce carbon emissions by 2.1 million metric tons.
- Advances in **geothermal heat pumps** have substantially reduced the heating and cooling loads of hundreds of thousands of residential, commercial, and institutional buildings across the United States. Over their lifetimes, the pumps installed between 1995 and 1998 are estimated to save $980 million in energy costs and reduce carbon emissions by 1.7 million metric tons.
- The development of 80 percent efficient **transpired solar collectors** have provided commercial and industrial facilities with a cost-effective means for preheating ventilation air. Over their lifetimes the 52 systems installed as of 1999 will save $10 million in avoided fuel costs.

Summary of R&D Successes

These 11 R&D successes have received approximately $230 million of support from DOE. The Inventions and Innovations Program, with a cumulative budget of $84 million, received the largest share of this funding, with other programs receiving funding ranging from $1 million to $45 million in DOE appropriations.

Additional investments have been made by the companies that manufacture and distribute these technologies. Typically, these companies were partners early in the R&D effort, thereby enriching the research program with the industry's knowledge of the manufacturing and marketing features required for success. For most of these projects, DOE funding came entirely through EERE; the vast majority of this funding was appropriated in the 1990s.

These 11 R&D successes have enabled the nation to save 5,050 trillion Btu of energy. Included in this figure is a 2,000 trillion Btu energy penalty averted because a DOE partnership accelerated the development of ozone-safe refrigerants by one to two years, resulting in an estimated $16 billion in savings. Diesel engine technologies developed by DOE, in cooperation with industry partners, are both cleaner and more energy efficient, saving approximately 2,180 trillion Btu, equivalent to 16 billion gallons of motor fuel, and reducing carbon emissions by about 40 million metric tons through 1997. An additional 112 trillion Btu of fossil energy has been replaced by DOE partnerships in wind turbine technology and transpired solar collectors, two of the renewable-energy R&D successes described in Box 1. Additional energy will be saved as the technologies that are currently installed continue to generate benefits, and as new equipment is put into use.

Some of the commercialized technologies (such as lightweight materials for automobile use and ozone-safe refrigerants) have captured significant market share. However, most of the commercialized technologies are still in the initial stages of market penetration. If they do in fact reach full deployment, they promise to deliver enormous benefits. For instance, if one million compact fluorescent torchieres were bought instead of halogen torchieres, $27 million in electricity costs would be saved each year and nearly $200 million would be saved over the average seven-year operation of the lamps. The lives saved from the avoided fire hazard of halogen torchieres would add significantly to the ultimate roll-up of benefits.

Significant reductions in carbon emissions can also be seen. Roughly 90 million metric tons of carbon emissions have been avoided due to the commercial success of these 11 EERE-developed and supported technologies, along with some significant reductions in the emission of nitrogen dioxide and particulate matter. Additional benefits have resulted from these recent commercial successes, including O&M cost savings, ozone protection, enhanced economic competitiveness, and greater energy security.

FIELD VERIFICATION, DEPLOYMENT, AND OUTREACH

EERE has developed strong partnerships with other government entities and the private sector to better leverage the federal investment in R&D and to facilitate the deployment of new technologies. These partnerships often involve other parts of DOE (the Offices of Fossil Energy, Nuclear Energy, and Science) and other federal agencies. EERE also works closely with its National Laboratories, businesses, state and local governments, universities, nonprofit organizations, international partners, and Congress to disseminate information and facilitate the deployment of technologies by the private sector, including working with the private sector to set research and development priorities.

Some of the technologies that these programs seek to deploy have been developed through EERE research and development programs. The Weatherization Program provides an example of this linkage. The retrofit measures used to improve the thermal integrity of homes occupied by low-income families include oil heaters with flame retention burners (a technology developed with EERE support), and the analysis software used to select retrofit measures for specific homes in the Weatherization Program is a product of EERE funding.

Some Recent Accomplishments

The nine field verification, deployment, and outreach accomplishments summarized below describe EERE programs that have a focus on the validation and deployment of existing technologies (Box 2). More detail on the level of DOE R&D investment and the actual benefits from these successes is available in Appendix A.

Summary of Field Verification, Deployment, and Outreach Successes

The investment of federal funds that generated the energy and cost savings benefits discussed in the accomplishments of these nine EERE deployment stories is about $480 million. More than half of this is cumulative investments in the Building Standards and Guidelines Program and the National Biomass Ethanol Program. Another $125 million is the 1998 budget for DOE's Weatherization Assistance Program. Utilities, companies and other partners involved in these programs have also contributed their expertise, time, and money to ensure the success of these programs.

The energy saved or replaced over the lifetime of technologies installed to date is 2,080 trillion Btu. Taken together, the ethanol fuels and Clean Cities programs have replaced about 1,580 trillion Btu of gasoline with ethanol. The energy savings include 108 trillion Btu accruing from the weatherization of low-income homes and 154 trillion Btu from the adoption of buildings efficiency standards. The total also includes 71 trillion Btu from recommendations in energy audits performed by some 30 Industrial Assessment Centers and 131 trillion Btu from 13 Motor Challenge Showcase Demonstration projects.

The value of the energy saved and the fossil energy replaced to date from these nine field verification, deployment, and outreach successes is considerable. Approximately $12 billion in oil-based fuels have been replaced as a result of the Ethanol Fuel Program, and almost $1 billion more has been replaced as a result of the Clean Cities programs, through 1998. $1.1 billion of the total has been saved to date due to building energy codes and standards and $300 million is cost savings from DOE-funded energy audits for small and medium-sized manufacturers. Further, $162 million in energy cost savings have resulted in 1999 from the retrofits that have resulted from Rebuild America partnerships, and $550 million in energy expenditures will be saved as the result of building retrofits enabled by DOE's Weatherization program. Additional benefits could result from the Federal Energy Management Program's Energy Savings Performance Contracts. If the full contract authority for the contracts put in place by 2000 is used, $10 billion of additional energy savings will result.

These nine field verification, deployment, and outreach programs will result in 13 million metric tons of carbon reductions. In addition to avoided carbon emissions, there have been, and will continue to be, reductions in nitrogen dioxide emissions and other harmful pollutants. Many other benefits have resulted from these nine programs, including thousands of jobs created, community development, and increased health and safety.

Box 2: Nine Field Verification, Deployment, and Outreach Successes

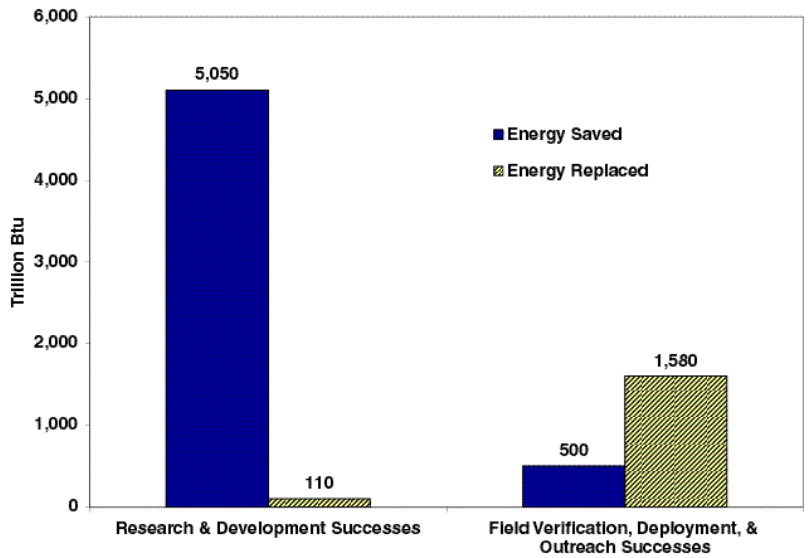
- DOE and its partner agencies retrofit 167,000 homes in 1998 under the **Weatherization Program**, which will save 108 trillion Btu and save occupants $550 million in utility bills over the 20-year life of installed energy-conservation measures.
- DOE has successfully used **building energy codes and standards**, supported by technical assistance and outreach efforts, to transform markets, resulting in energy cost savings of $1.1 billion in 1998.
- Two hundred and fifty **Rebuild America** partnerships are pursuing energy-efficient retrofits of 800 million square feet of commercial floorspace. Estimates of energy cost savings from these retrofits in 1999 are $162 million, showing the energy-efficiency payback that results when community networks are catalyzed.
- FEMP's innovative **Energy Savings Performance Contracts (ESPCs)** can now be used by federal agencies to contract with energy services companies to install energy-efficient systems and components, and pay for these improvements from the energy cost savings generated by the new systems. Since 1998, total contractor investment in the federal government is $405 million.
- Working in cooperation with **Bethlehem Steel**, the DOE Office of Industrial Technologies demonstrated a number of energy-saving and environmentally sound technologies and processes at the Burns Harbor plant that may be replicated throughout the steel industry and are saving the company over $8 million per year while reducing pollutant emissions.
- DOE's **Industrial Assessment Centers**, working through 30 universities, have provided over 7,600 energy and industrial process audits as of 1998 to small and mid-size manufacturing firms, generating recommendations that could save participating firms $300 million by the year 2000.
- Six recent demonstration projects where the DOE **Motor Challenge Program** provided technical assistance or advanced motor selection software to industry helped the firms install energy-saving motors in place of older, more energy-intensive units, thereby saving nearly $2 million per year and paying for the changes in just over a year.
- The **Clean Cities Program** is a voluntary, locally based government/industry partnership to reduce the use of gasoline by accelerating the deployment of alternatively fueled vehicles. The 139,000 alternatively fueled vehicles that have been deployed over the past five years reduced gasoline and diesel fuel use by an estimated 380 million gallons through 1998, and reduced carbon emissions by an estimated 400,000 metric tons. Over the life of the program, approximately $900 million worth of fuel has been saved.
- The **National Biomass Ethanol Program** has broken ground on the first commercial biomass-to-ethanol plant in October 1998 in Jennings, LA. This is part of a DOE effort to expand the domestic ethanol industry and production of a low polluting alternative to gasoline by developing and demonstrating new conversion technologies using agricultural residues and energy crops. The use of ethanol blends in gasoline has displaced $12 billion worth of oil-based fuels through 1998.

SUMMARY ANALYSIS

The activities in these 20 stories have received EERE funding of $712 million, less than 10% of the approximately $8 billion of EERE funds appropriated by Congress during the 1990s. Additional benefits have accrued from the balance of the budget that is not covered by this report's accomplishment metrics.

Looking at the bottom line in terms of energy, as represented in the graph below, these 20 R&D and deployment successes have saved more than 5,500 trillion Btu, 5,050 trillion Btu from EERE R&D successes, and almost 500 trillion Btu as a result of EERE field verification, deployment, and outreach successes. These savings are enough to meet the energy needs of all of the citizens, businesses, and industries located in the states of New York, Connecticut, and New Mexico, for one year (EIA, 1999a, Table 1). EERE technology and deployment programs have replaced another 1,700 trillion Btu of fossil fuels with renewable alternatives. This is equivalent to running all of the cars registered in the states of California, Florida, Mississippi, and West Virginia on ethanol rather than gasoline, for one year (Davis, 1999, Tables 2.6 and 2.11; Federal Highways Administration, 2000). Significant reductions in carbon emissions (103 million metric tons), have resulted from this decrease in burning fossil fuels.

Energy Saved and Replaced by 20 Recent EERE Accomplishments



As an order of magnitude estimate, savings to the nation from these 20 activities are estimated to be approximately $30 billion ($1998). This is based on the 5,500 trillion Btu of energy savings and the cost to consumers of an average Btu of energy consumed in 1998 (EIA, 1999b, Tables A2 and A3). In 1996, the General Accounting Office reviewed the success of five similarly situated technologies developed in the 1980s, and found a cumulative energy savings from all installations through 1996 to be $28 billion, or over $3 billion per year. All of these benefits will continue to grow as many of the technologies that have been commercialized with the support of EERE resources gain market share, and as emerging technologies achieve the technical breakthroughs and cost reductions necessary to successfully compete in the marketplace.

Compact fluorescent torchieres, spectrally selective glazings for windows, and lightweight materials for vehicles are examples of commercial products that are likely to produce much greater energy saving over the next decade than they have produced to date. Geothermal heat pumps installed through 1998 will replace 25 trillion Btu of grid-generated electricity and will save consumers $980 million over the

lifetimes of their operation. Wind turbine technologies are expected to replace significant amounts of fossil-fuel generated electricity capacity over the next several decades, leading to cleaner power and contributing to the nation's goal of energy security through fuel diversity.

BENEFITS OF FUTURE PROGRAMS

The following table is a reproduction of the estimated benefits of the EERE FY 2001 budget for DOE in terms of energy replaced, energy cost savings, and reductions in carbon emissions. Estimates are derived through EERE's Government Performance and Results Act (GPRA) methodology and are independently peer-reviewed.

Projected Benefits of DOE's Office of Energy Efficiency and Renewable Energy FY 2001 Programs By Sector in the Year 2005, 2010, and 2020

	Industry	Transportation	Buildings	FEMP	Power	Totals
	Total Primary Energy Replaced (quadrillion Btus)					
2005	.6	.2-.3	.5-.6	.05	.3-.6	1.65-2.15
2010	1.4-1.5	.9-1.0	1.0-1.3	.07	.9-1.8	4.27-5.67
2020	3.8-4.8	2.5	1.9-2.7	.07	2.5-4.3	10.77-14.37
	Energy Savings ($ billions)					
2005	2.1-2.2	1.7-3.3	3.0	.3	1.2-2.2	8.3-11.0
2010	5.5-6.8	8.4-9.9	8.4-10.3	.4	3.3-5.0	26.0-32.4
2020	17.3-19.3	20.1-22.6	15.0-21.7	.3	6.5-7.5	59.2-71.4
	Carbon Reductions (million metric tons)					
2005	10.3-11.9	3.8-4.6	9.2-11.2	1.0	2.7-12.1	27.0-40.8
2010	26.0-26.7	17.9-19.5	17.1-23.0	1.2	15.3-35.5	77.5-105.9
2020	65.3-99.8	46.0-50.1	34.4-47.4	1.2	45.1-88.3	192.0-286.8

Where the benefits are expressed as a range of values, the upper point was determined based on analysis conducted by EERE's sectors and reviewed by Arthur D. Little, Inc. The sectors analyze the impacts their programs will have on energy savings, cost savings, and carbon reductions if all program goals are met. The lower point of each range for energy replaced and carbon reductions was derived from an integrated analysis model that controls for interaction effects. This model-driven analysis is conducted by contractors external to DOE. The integrated analysis model accounts for inter- and intra-sector double-counting as well as market trends (*i.e.*, reductions in new electricity generation). The lower point of the energy cost savings range is calculated by multiplying the total fossil primary energy replaced, derived from the integrated analysis, by the sector's ratio of energy cost savings to total primary fossil energy replaced for that year.

The total benefits projected for the year 2001 from the FY2001 budget are quite small and are primarily the result of EERE's partnership and deployment programs. By 2020 the projected impacts are substantial, reflecting large benefits from both partnership and R&D programs. The amount of primary

energy replaced in the year 2020 is forecast to range from 10.8 to 14.4 quadrillion Btus, which is 9 to 12% of the 121 Quads that the United States is forecast to consume in the year 2020 (EIA, 1999b, Table 1, p. 7). The carbon reductions forecast for the year 2020 represents an even more significant percentage of the projected carbon emissions in 2020—ranging from 10 to 14% of the forecasted total emissions.

A recent report from an independent consulting firm (Arthur D. Little, 1999) determined that the energy savings and emission reduction estimates contained in this table are "realistic and credible." Arthur D. Little reviewed the information on projected energy savings and greenhouse gas emissions reductions to ensure the validity of estimates and assumptions. The report describes how the firm conducted the external review and concludes that the firm "believes that the estimates of the future benefits as summarized in this report are credible due to the rigorous review."

CONCLUSION AND NEXT STEPS

The accomplishments described in this report display positive impacts on real people and places that can be linked to EERE research, technology development, demonstration, and deployment activities. They document quantifiable, measured, tangible, and intangible impacts and benefits.

This report represents the most comprehensive effort taken to date to describe EERE's accomplishments and to quantify the benefits resulting from the nation's investment in its programs. EERE intends to increase the rigor of its future benefit-cost assessments and plans to report periodically on the successes of its programs. Recommended improvements include more rigorous documentation of costs, benefits and the impact of EERE involvement; more frequent application of cost-benefit analysis and case study methods, and more consistent cost and benefit assumptions and applications across EERE programs, so that results can be more easily aggregated.

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