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Clean Energy Partnerships: A Decade of Success

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

DISCLAIMER

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
Assistant Secretary
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

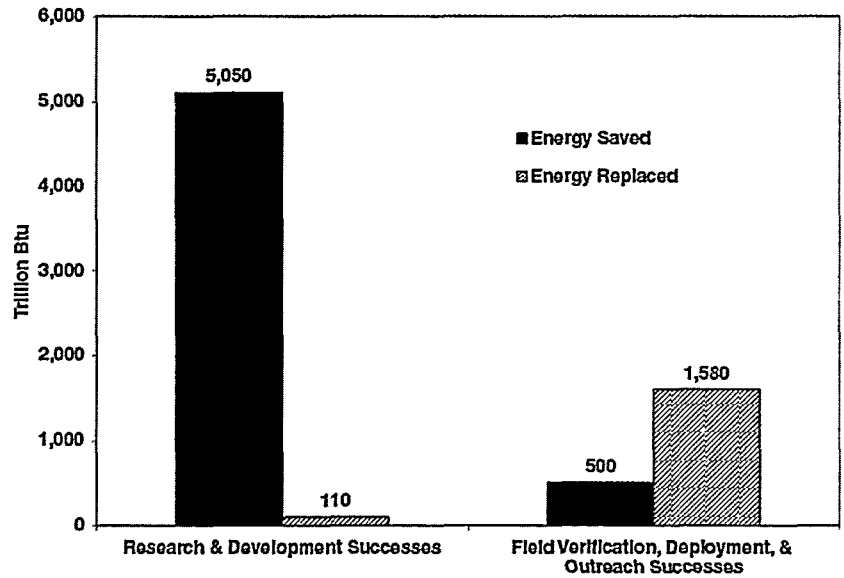
- DOE and its partner agencies retrofit 167,000 homes in 1998 under the **Weatherization Program**, which will save 108 trillion Btu and save occupants $550 million in utility bills over the 20-year life of installed energy-conservation measures.
- DOE has successfully used **building energy codes and 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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RESEARCH AND DEVELOPMENT SUCCESSES

Improvements in energy use and production technologies and practices through R&D programs provide the building blocks for a cleaner, more efficient and diverse energy economy. The imperative of investing in a strong R&D portfolio is reinforced by recognition of the long periods of time associated with significant changes in our energy infrastructure. Research and development itself often takes one or two decades to yield technological breakthroughs. The life expectancy of major energy supply and end-use technologies also extends to many decades. Investments made every day commit the nation to an energy path for what can be a considerable period of time. To the extent that economically attractive, clean, and efficient technologies are chosen, both the economy and the environment benefit. Thus, a robust energy R&D program is needed to enable the country to achieve a healthy and prosperous future.

EERE's strategy includes creating R&D partnerships among energy companies, energy-intensive industries, universities, and our national laboratories to advance the development of new energy technologies and practices. Such R&D alliances help maximize the efficiency of the technology R&D process by leveraging public and private R&D resources, and bringing together interdisciplinary teams of scientists, engineers, and analysts to deliver technology results acceptable to energy markets.

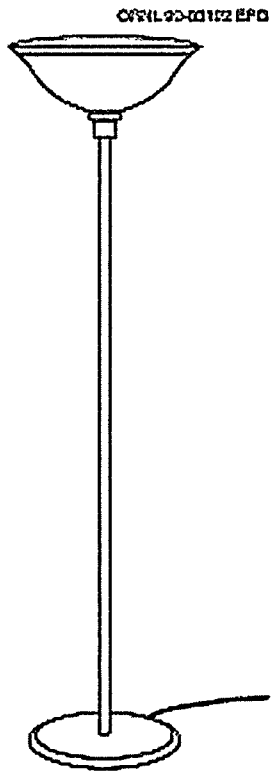
A SAMPLE OF R&D SUCCESSES

This section describes 11 EERE R&D successes resulting in commercialized technologies that are successfully competing in the marketplace.

A Sample of Research and Development Successes

Buildings	Industry
➢ Compact Fluorescent Torchiere	➢ Oxy-Fuel Fired Glass
➢ Ozone-Safe Refrigerants	➢ Inventions and Innovations Program
➢ Spectrally Selective Glazings	
Transportation	**Power**
➢ Lightweight Materials	➢ Parabolic Troughs
➢ Diesel Engines	➢ Wind Turbine Advances
	➢ Geothermal Heat Pumps
	➢ Transpired Solar Collectors

Compact Fluorescent Torchiere

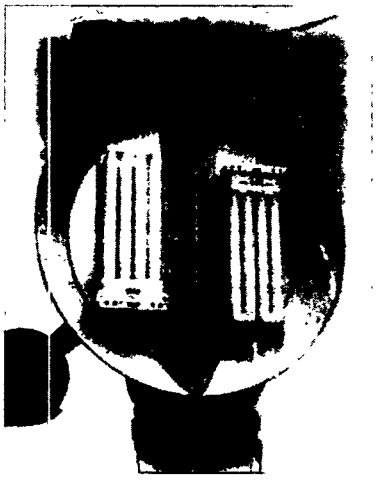


Halogen torchiere lamps surged in popularity in the 1980s and 1990s. Their crisp white light, dimming capabilities, low glare, and low cost make them very attractive to consumers. As the number of halogen torchieres in use grew to an estimated 40 million, evidence of problems with the technology surfaced. The high operating temperatures of the lamp and the open reflector design create a fire hazard that has been blamed in as many as 260 fires and 12 deaths in the United States. The lamp's energy-intensive halogen bulbs, which use 300 to 500 W, were by 1996 consuming roughly 16 billion kWh of electricity per year, the output of six typical (500 MW) power plants.

DOE, working through researchers in the Energy-Efficient Fixtures Program at Lawrence Berkeley National Laboratory (LBNL), recognized the growing impact of halogen torchieres on residential energy use and realized that they could develop fixtures that offered the same attractive features, but used a more efficient light source that would also eliminate the fire hazard. LBNL researchers identified compact fluorescent lamps (CFLs) as a suitable alternative and set out to develop an appropriate design.

DOE/LBNL worked initially with several major lamp and ballast manufacturers and later with a small, entrepreneurial company to develop a prototype and accelerate commercialization. This product turned out to be well suited to market needs and stimulated other manufacturers to develop and introduce similar products.

The DOE Role



An overhead view of the compact fluorescent torchiere developed by the LBNL fixtures lab.

In 1995, LBNL researchers ran a series of tests on halogen torchieres. Infrared thermography was used to determine heat output. A swing-arm goniophotometer, developed at LBNL, was used to measure light output and the distribution of light. Power, power factor, and total harmonic distortion were also measured. Working with these test results, the researchers built several CFL-based torchiere prototypes with a variety of lamp and reflector configurations. Their best design used two 36-W F-type lamps to produce 50% more light than a 300-W halogen torchiere with only 25% of the energy consumption. With Emess Lighting Inc., LBNL worked to determine which prototype would provide the best light with the simplest design and easiest manufacturing process. Energy Federation Incorporated (EFI) also worked with LBNL to optimize the reflector in their torchiere design. LBNL's input was invaluable to light fixture manufacturers, who generally lack technical expertise in compact fluorescent or other lamp technologies.

Lab researchers and manufacturers agree that LBNL's involvement acted as a catalyst, accelerating the commercialization of the alternative torchieres. Emess Lighting had experience developing fixtures for compact fluorescent lamps, but operating problems and the high costs associated with early CFL technologies had undermined their efforts. As a result, the company was hesitant to take a leading role with a new product unless the technology was clearly ready and its marketability proven. LBNL's research showed how advances in lamp quality and electronic ballasts had led to CFL technology that could exceed the performance of the halogen torchiere, would pose no safety problem, and would use far less energy. To assure manufacturers that a market existed for CFL torchieres, DOE and LBNL identified volume markets for the technology: universities, military bases, and commercial buildings. They also

played an important role in establishing CFL torchiere "swaps" and fixture installations on two university campuses and at Bolling Air Force Base.

Five manufacturers have introduced CFL torchieres with a range of styles and prices (compared in Table 1). All qualify for the Energy Star® Residential Fixtures labeling program, and some utilities are sponsoring discounts. The lamps can now be purchased through a variety of retail outlets and websites. Some websites automatically calculate any utility rebates and deduct the rebate from the lamp's cost. LBNL's CFL torchiere design was awarded the 1997 Popular Science "Best of What's New" Grand Prize Award for Home Technology.

Table 1: Product Comparison

Manufacturer	Lamp Watts	Light Output (lumens)	Dimmability/ Switchability
Standard Halogen	300	3,500	full dimming
Catalina Lighting	67	4,200	full dimming
Emess Lighting	72	4,200	100%, 50%
Energy Federation Inc.	52	3,600	100%, 50%
Energy Federation Inc.	78	4,200	100%, 66%, 33%
Good Earth Lighting	67	4,200	full dimming
Lights of America	50	4,050	100%, 62%, 38%

The LBNL Energy Efficient Fixtures Program is building on its strong relationship with the lighting industry by offering their assistance to companies seeking to commercialize energy-efficient lighting products. The lighting industry has expressed a strong interest in furthering this relationship with LBNL.

Benefits and Costs

A leading fixture manufacturer estimated total sales of the CFL torchieres at 5,000 in 1997 and growing to 200,000 in 1998. Others predict sales reaching one million units per year within the next few years. CFL torchieres (using 55 to 78 W) sell for $48 to $159 retail; halogen torchieres sell for an average of $20. Despite its higher initial cost, the life cycle costs of the CFL torchiere demonstrate its cost-effectiveness, with a payback period of less than two years, based on cost of $70 (versus $20 for a halogen torchiere); CFL lamp life of 10,000 hours (versus 2,000-hour life with a $6 replacement cost for halogen lamps); lamp usage of 4 hours per day; and electricity cost of $0.08 per kWh.

The electricity saved in 1998 from the sale of 200,000 CFL torchieres (instead of halogen torchieres) is an estimated 69 million kWh. The electricity saved over the seven-year life of the 200,000 lamps is estimated to be 480 million kWh (or the equivalent of 5.2 trillion Btu). Every halogen torchiere replaced by a CFL torchiere also represents the removal of a fire hazard and the prevention of fires, loss of lives, and property damage. DOE invested approximately $300K in R&D on compact fluorescent torchieres between 1995 and 1997.

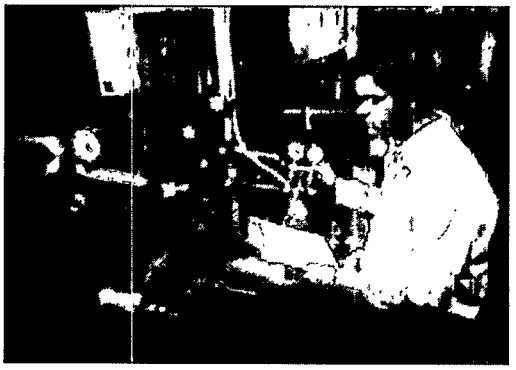
For More Information

Website: **http://eetd.lbl.gov/BTP/torchoverview.html**

Geller, Howard, and Jennifer Thorne. 1999. "U.S. Department of Energy's Office of Building Technologies: Successful Initiatives of the 1990s." American Council for an Energy Efficient Economy: Washington, D.C. , www.aceee.org/pubs

Ozone-Safe Refrigerants

In the late 1980s and early 1990s, manufacturers of refrigeration equipment—refrigerators, freezers, air conditioners, and heat pumps—faced several challenges. First, the manufacture and use of chlorofluorocarbons (CFCs) would be phased out as of December 31, 1995, under the Montreal Protocol on Ozone-Depleting Substances. Second, appliance standards mandated by the National Appliance Energy Conservation Act of 1987 (NAECA) would take effect in 1993, requiring significant advances in energy efficiency. To further complicate matters, some of the early alternatives to CFCs increased energy consumption and were linked to global warming.



An ORNL engineer, Ed Vineyard, checks instrument readings during a test of chlorine-free refrigerant mixtures.

DOE responded to these challenges by initiating programs of joint research and development with the chemical, appliance, and air conditioning industries. DOE's leadership galvanized industry resources and pulled together federal R&D capabilities to address the problem. The research on ozone-safe refrigerants resulting from these collaborations accelerated the entry of alternative refrigerants in commercial applications, allowing U.S. industry to phase out CFCs two years before the Montreal Protocol deadline and to meet NAECA requirements, and saving an estimated $16 billion in energy expenditures.

The DOE Role

Beginning in 1985, DOE funded Oak Ridge National Laboratory (ORNL) to evaluate potential replacements for CFC refrigerants. Researchers analytically screened over 200 compounds and selected 14 that were also acceptable in terms of properties such as volatility, flammability, stability, and boiling point range. Several refrigerant suppliers synthesized these compounds for testing. Researchers at ORNL's Alternative Refrigerants Calorimeter Facility tested sample quantities of CFC-replacement fluids, measuring the energy performance and cooling capacity of each. Based on their results, ORNL researchers suggested changes in the composition of refrigerant blends to their industry collaborators, who produced the new blends for further testing.

Beginning in 1987, DOE also funded the National Institute of Standards and Technology (NIST) to conduct basic research into the fundamental thermophysical properties of refrigerants, along with systems testing, modeling, and evaluation of hardware. Early results from ORNL and NIST indicated that existing replacements for CFC refrigerants could increase the energy consumption of refrigerators by 8%. This potential energy penalty sounded an alarm in the appliance industry, which was facing deadlines for compliance with new NAECA standards. DOE and its industry collaborators took the news as fair warning and accelerated research efforts on all fronts.

Phasing out ozone-depleting refrigerants was more complex than simply identifying new refrigerants. Bottom-line performance depended on thousands of interacting variables, and the wished-for "drop-in" replacements for CFCs failed to materialize quickly. One important obstacle, in terms of both mechanical factors and energy efficiency, was the incompatibility of the CFC alternatives with the lubricants and materials used in existing equipment designs. One incompatibility identified by ORNL's research could have imposed a 45% energy penalty. DOE addressed this issue in 1991 by funding the Material Compatibility and Lubricant Research (MCLR) program to identify lubricants and materials suitable for

use with alternative refrigerants. This program was jointly managed by DOE and the Air Conditioning and Refrigeration Technology Institute (ARTI).

Prior to the DOE support to ARTI there had been no publicly accessible compilation of information on what had been accomplished in terms of research and testing of new refrigerants, lubricants and their effects on equipment materials. As part of the MCLR activities, the ARTI established a Refrigerant data base that is a comprehensive reference source of published reports and includes the results of over forty research projects from the DOE/ARTI MCLR research. This data base now contains more than 6100 entries and has been a primary source of information on new refrigerant issues for the industry.

The Heat Pump Design Model, a public-domain computer program developed by ORNL, was an important tool in developing safe and effective CFC alternatives and working with industry to redesign equipment to work with those refrigerants. The program was used in ORNL's studies and by manufacturers representing over a third of the U.S. air conditioner and heat pump market to determine capacity and efficiency of new refrigerants by modeling their operation in alternative equipment designs.
DOE's leadership brought into play the resources needed for a successful industry-government R&D effort that led to the development of optimized, environmentally friendly refrigerants for energy-efficient appliances. In a letter of appreciation to DOE, ARI's Vice President of Research and Technology applauded the excellent government/industry partnership and the "approach of conducting pre-competitive research, the results of which industry can tailor to its needs."

Benefits and Costs

All of the refrigerators, freezers, air conditioners, and heat pumps now available to consumers use refrigerants, developed by industry in collaboration with DOE, that cause little or no damage to the stratospheric ozone layer. According to industry, DOE's collaborative research made it possible for the United States to complete an early phase out of CFCs in many applications by 1994, two years earlier than required. Without DOE's program of collaborative research, the United States would have paid a huge price for a sacrifice in energy efficiency.

Without DOE's collaboration with industry to accelerate the identification of these alternatives and to adapt equipment to maintain the energy efficiency achieved in appliances using CFC refrigerants, the nation's energy use would have increased by 1 to 2 quads per year in the mid-1990s. Using the more conservative estimate of 1 quad of savings per year and assuming 2 years of benefits results in an estimated total energy savings of 2 quads. This is equivalent to a $16 billion savings in the nation's energy expenditures. The early development of CFC substitutes in the United States also helped increase exports of air-conditioning and refrigeration products.
DOE invested approximately $15 million in R&D on ozone-safe refrigerants between 1985 and 1998.

The Big Picture

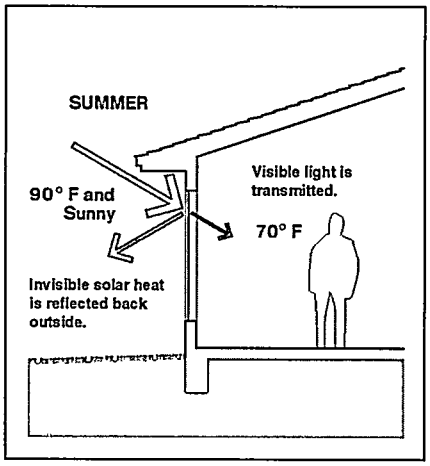
In addition to meeting its near-term goals, this DOE R&D program helped lay the groundwork for appliance manufacturers to meet the higher efficiency standards that will be effective in 2001.

For More Information

DOE Office of Building Technology, State and Community Programs—Advanced Refrigeration Program: www.ornl.gov/ORNL/BTC/warming.html

Vineyard, E.A., J. R. Sand, and T. G. Statt. 1989. "Selection of Ozone-Safe, Nonazeotropic Refrigerant Mixtures for Capacity Modulation in Residential Heat Pumps," ASHRAE Transactions 95(1), 34-46.

Spectrally Selective Glazings



Since helping to develop the first generation of low-emissivity (low-E) window coatings, DOE has continued to work with glass and window manufacturers on spectrally selective coatings for warmer parts of the country. Spectrally selective coatings admit as much daylight as possible while blocking transmission of ultraviolet and infrared "heat" radiation, thereby reducing solar heat gains in summer while still preventing loss of interior heat in winter. The opportunity for spectrally selective glazings is illustrated by the fact that low-E windows have a residential market share of 50% or more in the northern regions of the country, but only 20% or less in the Southeast and Southwest.

Caption: Spectrally selective windows can cut cooling costs in hot climates by 10 to 25%

The DOE Role

In the mid-1980s, Lawrence Berkeley National Laboratory (LBNL) analyzed the energy impacts of windows in typical houses throughout the United States, showing that reducing solar heat gain in hotter climates could substantially cut energy costs, and that even in colder climates cooling costs due to windows were significant. This information helped convince Cardinal IG, a major glass manufacturer, to introduce solar control low-E glazings and Andersen Windows to adopt solar control low-E on a wide scale.

DOE's national laboratories worked to bring spectrally selective glazings into the mainstream window markets during the late 1980s and early 1990s through their technical studies and interactions with the windows and glass industry:

- A workshop in 1992 to publicize the benefits of the technology and to showcase product offerings, applications, and marketing opportunities was organized by LNBL in 1992. Utilities began to subsidize the costs of spectrally selective glazings as part of their demand-side management programs.
- LBNL tested several spectrally selective glazings in the mobile window thermal test facility (MoWiTT) to verify their energy performance. These tests demonstrated to window manufacturers, utilities, and code officials that the effects of these invisible coatings were real.
- LBNL's computer model, WINDOW, used throughout the industry to quantify performance of windows, was upgraded to properly characterize this new class of spectrally selective products.
- The National Renewable Energy Laboratory evaluated the impacts of spectrally selective glazings on cooling energy use in actual homes in hot climates. This demonstration of energy and cost savings boosted industry marketing efforts, and encouraged the building industry to adopt selective glazings and more utilities to include windows in their demand-side management programs.

In the 1990s, DOE contributed to rating and labeling efforts to ensure that the performance of selective glazings is accurately represented to consumers, architects, and specifiers. LBNL worked with the glass industry to develop procedures for measuring glass properties and a database of these properties. This database, used in conjunction with the WINDOW program, was tied in with National Fenestration Rating Council (NFRC) procedures for accurately rating spectrally selective glazing products. NFRC established and implemented the rating, labeling, and certification program.

Benefits and Costs

Spectrally selective windows are one piece of the puzzle in the "whole-buildings" approach of DOE's Building Technologies, State and Community Programs (BTS). Building America and other BTS programs are developing the next generation of energy-efficient houses, which will use at least 30% less energy than the standards set in the 1998 Model Building Code. Designs for these houses generally start with spectrally selective low-E windows because of their central place in the energy equation. Using these windows plus extra insulation decreases the need for heating and cooling so that smaller, less expensive HVAC systems can be used, which lowers construction costs as well as saving energy. Spectrally selective low-E windows are also chosen because they significantly increase thermal comfort and reduce condensation, benefits that may seem even more important to some occupants than energy savings.

Today spectrally selective products are manufactured by the major glass manufacturers and some films manufacturers and are used in about 15% of new low-E windows. Simulations, tests, and monitored buildings demonstrate that using solar control windows can reduce cooling energy use in air-conditioned homes by 10–25%, depending on climate and site shading. They can also reduce lighting energy use in commercial buildings because they transmit more visible light than the conventional tinted films used to cut solar heat gains.

Retrofitting with selective glazings can pay back in four to ten years for commercial buildings in most parts of the United States. The payback is even faster in new buildings where the incremental cost is lower and the air conditioning system can be downsized. Double-pane glazing with a spectrally selective coating costs 10 to 20% more than ordinary double-pane glazing. Using spectrally selective windows in retrofit applications where labor accounts for a significant proportion of the cost adds only about 5% to the total price of the job.

If all new windows sold in hotter climates had spectrally selective coatings, cooling energy use in 2010 due to heat gains through windows would fall by about 0.19 quads, a 39% savings. At the projected price of electricity in 2010 ($0.073/kWh in 1996 dollars), this implies energy bill savings of $1.3 billion per year. If all new windows sold throughout the country contained spectrally selective coatings, heating energy use due to windows would be reduced by about 0.24 quads (19%) in 2010. With projected energy prices for heating fuels, this savings would be worth about $1.2 billion per year. Thus, full adoption of spectrally selective coatings in new residential windows could potentially result in total (heating and cooling) savings of about $2.5 billion per year by 2010.

DOE invested $3 to 4 million in R&D and rating and labeling efforts in support of spectrally selective glazings from 1986 through 1996. DOE continues its efforts to accelerate the deployment of energy-efficient windows through its support of the Efficient Windows Collaborative (EWC), an organization with more than 50 members, including the leaders of the window and glass industries who are committed to manufacturing and promoting energy-efficient windows. The EWC's Efficient Windows web site is supported by DOE's Windows and Glazings Program and the EWC's collaborating members. This web site provides unbiased information on the benefits of energy-efficient windows, descriptions of how they work, and recommendations for their selection and use.

For More Information

Efficient Windows Collaborative web site: www.efficientwindows.org

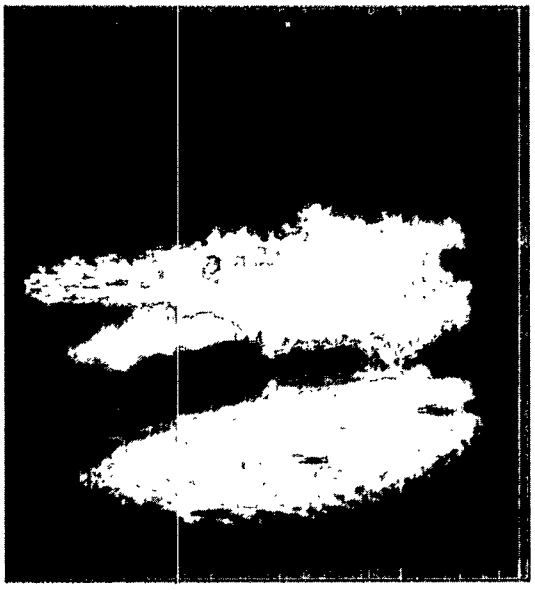
Klems, J. H., M. Yazdanian, and G. O. Kelley. "Measured Performance of Selective Glazings." *Proceedings of Thermal Performance of the Exterior Envelopes of Buildings VI*, Clearwater Beach, Fl, 1995.

Oxy-Fuel Fired Glass

The Office of Industrial Technologies (OIT), working in close cooperation with industrial partners, contributed $1 million in 1991 to demonstrate the practical application of research and development on oxygen-fueled glass furnace technologies. The success of the demonstration confirmed the commercial viability of oxy-fuel firing, encouraging the widespread adoption of this process. In 1999 approximately 30 percent of all glass made in the U.S. comes from oxy-fuel fired furnaces. The annual energy savings attributed to oxy-fuel systems in the U.S. in 1997 was over 3.4 trillion Btu, an annual savings of $7.2 million, and cumulative energy savings through 1997 totaled 13 trillion Btu, a savings of $27.5 million. Cumulative carbon reductions attributed to oxy-fuel firing total 0.19 MMT.

Success in Reaching Energy and Environmental Goals

OIT funds R&D and disseminates objective data that improves glass making, determining research priorities with the OIT Glass Team's industrial and university partners. OIT engages these partners in workshops and symposia. A participant from glassmaker Corning commented on one such workshop: "I was particularly impressed by the size and diversity of this gathering, the candidness of the participants, and the positive, cooperative spirit that prevailed throughout the proceedings. There was a strong sense that, working together, we can find technical solutions to the remaining challenges posed by oxy-fuel technology and the net savings will be well worth the effort."



An ultra-low NO_x burner firing fuel and oxygen into a rolled flat-glass furnace.

OIT-funded research in combustion includes burner design, sensors, modeling, and refractories. DOE's continuing support of the oxy-fuel process was demonstrated in 1997 through the award of $17.4 million for cost-shared glass production research. Three of the five projects funded focus on the oxy-fuel process. The projects aim to extend the lifespan of furnace refractories, improve burner and sensor designs, develop expert systems controls, and improve the economics of oxygen production.

Oxygen enrichment of glass furnace fuel streams is key to industry reaching its energy and environmental goals. Glass production is an energy- intensive process. In 1994, the domestic industry consumed over 200 trillion Btu of process energy at a cost of more than $1.3 billion. The production of glass also presents considerable environmental challenges. By using oxygen instead of air, oxy-fuel firing can cut NO_x emissions more than 80 percent, lower particulate emissions by 25 percent, and reduce furnace energy requirements.

Benefits and Costs

The remarkable benefits generated to date foreshadow the benefits expected from present research efforts:

- By retrofitting oxy-fuel firing technology to a wine manufacturers' bottle production facility, OIT and its industrial partners achieved energy savings of 25 percent while reducing NO_x emissions by over

80 percent and particulate emissions by about 25 percent. OIT contributed $1 million to the demonstrations' $1.409 million budget.

- Typical oxy-fuel systems can now be installed at average capital costs of $50 to $100 per annual ton of oxygen capacity , with a simple payback of 2-4 years.

For More Information

For more information on how oxy-fuel firing is meeting the energy and environmental goals of the glass industry, please visit OIT's Glass Industry of the Future website at http://www.oit.doe.gov/glass/

Inventions and Innovations Program

The Inventions and Innovations Program (I&I) was established in 1974 to assist the development of inventions not related to nuclear energy and having outstanding potential for saving or producing energy. Since then, over 32,000 inventions have been evaluated by the National Institute of Standards and Technology for technical merit, and about 740 have received commercialization and financial assistance from DOE. Approximately 500 of these have been supported by DOE grants.

This cross-section of wood shows lignin bonding the hollow tubes of cellulose together.

Lenox Polymers, a Michigan-based start-up firm, benefited from one such grant. Financial and technical support provided by the Department of Energy's Office of Industrial Technologies' Inventions and Innovations (I&I) program, a component of the Energy-Related Inventions Program, allowed Lenox Polymers to develop specialty performance resins using lignin. Lignin, the natural glue that holds together tree fibers (shown here), is extracted from a by-product of paper mills called black liquor. Lenox Polymers now manufactures resins that save valuable petrochemical resources that are used to produce traditional petroleum-based resins. The company's products are now used in over 20 different applications, and sales for the start-up company topped $500,000 in 1997.

The Lenox Polymer Story

In 1984, the Inventions and Innovations program awarded Lenox Polymers a $96,914 grant to support development of a patented, domestically produced, renewable product. This grant covered about 10 percent of the development costs, including proof of concept and scale-up of the resin production process from the laboratory to commercial pilot scale.

The feedstock for Lenox resins is black liquor, a byproduct of pulp and paper mills. Roughly 50 billion tons of black liquor is produced each year; 90 percent of this is used within the mill, leaving about 10 percent available for use in the Lenox process. Using even a fraction of these 5 billion tons of excess black liquor will provide not only useful products from waste, but also relieve overloading of wood pulp recovery boilers. Lenox' natural polymer is environmentally friendly and free of potentially carcinogenic substances such as formaldehyde, phenol, and styrene found in oil-based substances.

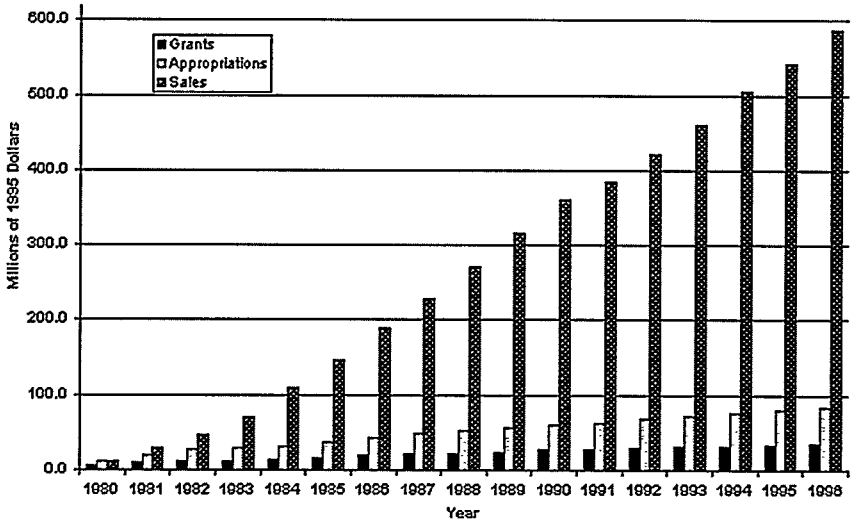
There are many applications for the Lenox resins. They can be used as foundry resins for metalcasting, wood particulate binders (for plywood and particleboard), and in compression molding polymer systems. When Lenox polymers are used in foam materials, the foam materials have a darkened color, but are also moisture resistant, flame and heat resistant, and have higher strength and toughness. By replacing polyesters and polyurethane resins, nitrous oxide (N_2O) emissions related to the production of these petrochemical-based resins will be cut by 4.2 to 8.4 thousand metric tons by the year 2010.

Benefits and Costs

The success of Lenox Polymers is not unique. Since the inception of the Inventions and Innovations Program, DOE and Oak Ridge National Laboratory have monitored and documented the commercial progress of supported inventions and innovations (Perlack et al., 1998). Of those inventions supported by grants, 25% have had commercial sales — a success rate generally higher than technological innovations overall. Total cumulative direct and licensed sales through 1996 now exceed $700 million (1995$); cumulative sales of spin-off technologies have reached $90 million (1995$). Program expenditures total $84 million through 1996.

As shown below, the inventions program has generated a 20:1 return in terms of the ratio of sales to grant dollars and an 8:1 return in terms of ratio of sales to total program expenditures. In 1996, I&I inventions supported the equivalent of nearly 1,200 full-time jobs, generating over $6 million in federal income taxes (i.e., more than I&I's annual appropriations). Energy savings attributable to grant-funded inventions were estimated at 80 trillion Btu, which amounts to a savings of $190 million (1995$). The reduction in carbon emissions associated with these commercially successful inventions exceeded 1.6 million metric tons in 1996.

Congressional appropriations for the program have totaled $84 million (in 1995$) from 1980 through 1996.



Cumulative grants, appropriations, and sales associated with DOE's inventions program.

For More Information

Perlack, R.D, C.G. Rizy, C.A. Franchuk, S.M. Cohn, *Commercial Progress and Impacts of Inventions and Innovations,* (Oak Ridge, TN: Oak Ridge National Laboratory), August 1999.

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of Industrial Technologies, "Inventions & Innovation Success Story – Environmentally-Friendly Polymer Replaces Petroleum Based Resins, available at http://www.oit.doe.gov/inventions/pdfs/lennox.pdf

Lightweight Materials for Automobile Structures

Automobiles account for almost two-thirds of the nation's gasoline consumption and about one-third of total U.S. energy use. About 75% of a vehicle's fuel consumption is directly related to factors associated with weight. Heavier vehicles use larger engines, bulkier drivetrains, and more massive chassis, and require more energy to accelerate, decelerate, and overcome rolling resistance. They also deliver more kinetic energy to other vehicles in automotive crashes.

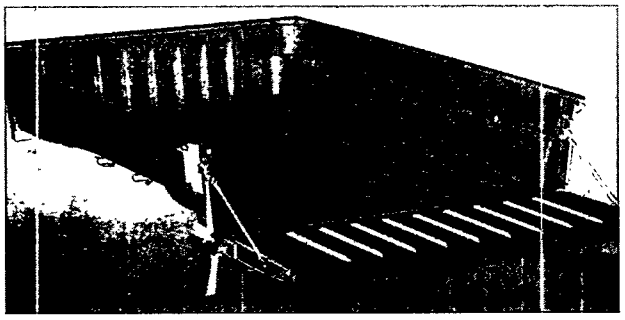
Lightweight materials are critical to the development of highly fuel-efficient vehicles. Since 1991, the DOE has worked with automobile manufacturers and their suppliers to develop lighter materials for primary structural applications. The challenge facing these programs is to produce lighter materials at production rates and costs comparable to those of current materials. DOE's objective is a 50% average weight reduction in body and chassis of 50% by 2004 and a 60% by 2011.

DOE Role and Technology Description

Using currently available lightweight materials could reduce vehicle weight by more than 60%. However, the cost of these materials, design capabilities, and associated manufacturing processes are still inadequate to produce cost-effective vehicles. Research supported by DOE is focusing on new, reliable joining technologies, lower-cost aluminum sheet materials, high-volume production technologies for fiber-reinforced composite materials, more reliable continuously cast aluminum components with improved performance capabilities, and innovative processing technologies for lower-cost carbon fiber materials. The goal is to give automotive designers multiple material options for future structures by removing technical and economic obstacles to producing advanced materials.

Metals and reinforced polymers are the two families of materials now under development. Among the metals, magnesium alloys and aluminum have the highest priority; metal matrix composites, titanium alloys, and intermetallics are important in longer-range plans. Among the polymers, reinforced thermosets and lower-cost, high-stiffness reinforcements are the highest priorities, with advanced thermoplastic materials being important for future development.

New technologies for working with these advanced materials must also be developed. Standard processes must be adapted or new ones developed to optimize quality and performance. New design methodologies and performance models as well as rapid, cost-effective, production-scale processes for the new materials will also be needed. Additional knowledge is needed regarding recycling of materials, joining technologies, crash performance, material durability, and lifetime performance.



Glass-fiber-reinforced all-composite pickup truck bed

Benefits and Costs

Benefits. Automobile companies have done an exceptional job of reducing the weight of vehicles over the last two decades—partly by making smaller cars, which has reached its limits of consumer acceptance, and partly by incorporating nonferrous materials into secondary vehicle systems. Average automobile weight has been reduced by nearly 25% while fuel economy has doubled. DOE's efforts to develop light weight materials such as aluminum for automobile applications have saved more than 6.0 billion gallons of motor fuel and reduced carbon emissions by 15 million metric tons. The dollars saved in oil-based fuels over the period from 1978-1997 is estimated at about $7 billion.

More extensive use of lightweight materials will further improve automobile fuel efficiency. There is still significant potential to reduce the weight of the primary (load bearing, crash critical) structural components, which are made almost exclusively of ferrous materials. In general, every 10% reduction in weight leads to a 6% mpg gain.

System	Current reference vehicle weight (lb)	Vehicle target weight (lb) for 2004	Mass reduction
Body	1,134	566	50%
Chassis	1,101	550	50%
Powertrain	868	781	10%
Fuel/other	137	63	55%
Curb weight	3,240	1,960	40%

Costs. The next steps in reducing the weight of cars will require significant capital investment by suppliers to the automobile industry to increase the production of materials such as aluminum and magnesium and to expand industries to produce carbon-fiber-reinforced materials. For example, to produce the carbon fiber potentially needed to meet demands in 2015 could require an investment of $4.6 billion. Retooling the automobile industry to use lighter materials will also require significant investment capital, but will likely occur with normal retooling as equipment life cycles end. There will be costs associated with developing the infrastructure necessary to repair, recycle, and dispose of these materials.

The cumulative DOE investment in aluminum lightweight materials from 1978 through 1997 was about $40 million. Private investment will be much greater and heavily concentrated in technology implementation.

The Big Picture

The OAAT strategy focuses on researching, developing, and validating technologies to produce market-competitive automobiles with dramatically improved fuel efficiency and no increase in emissions. OAAT aims to develop an 80-mpg, five-to-six–passenger vehicle by 2004 and, by 2011, six-passenger alternative-fuel vehicles that achieve zero emissions and 100 mpg. In addition to developing advanced materials, OAAT will sponsor development of advanced propulsion system technologies, advanced heat engines, fuel cells, high-power energy storage, power electronics, new fuels, and electric power batteries. Key performance milestones for lightweight materials technology R&D through 2011 are charted below.

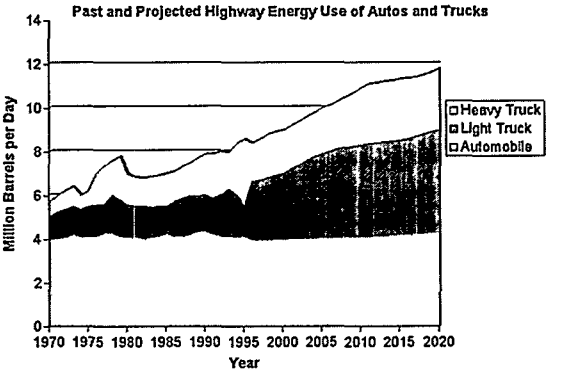
1994	1998	1999	2000	2004	2011
50% weight reduction at 2× cost of steel body and chassis	50% weight reduction at 1.5× cost of steel body and chassis	→	→	50% weight reduction at 1× cost	60% weight reduction at 1× cost

To reach these milestones, R&D activities are transitioning from developing glass-reinforced polymeric matrix composites to developing lighter carbon-fiber-reinforced polymeric matrix composites. In addition, research is focusing on using lighter metal-matrix composites for brakes, titanium for springs, and magnesium for joints.

For More Information

Office of Transportation Technologies, Office of Energy Efficiency and Renewable Energy, Department of Energy, *Office of Advanced Automotive Technologies R&D Plan, Energy-Efficient Vehicles for a Cleaner Environment*, March 1998.

Cleaner and More Efficient Diesel Engines



Trucks—pickups, sports utility vehicles (SUVs), and heavy freight hauling trucks—are the fastest growing fuel consumers in the transportation sector. Large-displacement compression-ignition diesel engines are the most fuel-efficient engines available to heavy vehicle manufacturers and operators. Current diesel engines offer peak thermal efficiencies of 44 to 45%, far above the 30% efficiency of conventional spark-ignited engines. Putting diesel engines in lighter trucks (classes 1-3) would offer significant fuel savings. DOE-sponsored R&D activities are performed in conjunction with industry and focus on enhancing the efficiencies of diesel engines for light and heavy trucks.
Greater fuel efficiency equates to proportional reductions in emissions of CO_2, the main contributor to global warming. The proliferation of SUVs as passenger cars may significantly increase overall fuel consumption and therefore the greenhouse gas emissions). Advanced diesel engine technology could help offset this trend. Increasingly stringent air pollution standards and heightened awareness of the need for energy-efficient engines are spurring renewed diesel engine research. DOE's goal is to develop "clean" diesel engines for light trucks that are 35% more efficient than current gasoline engines and to improve the thermal efficiency of heavy diesel engines for large trucks (Classes 7 and 8) to 55%.

The DOE Role

DOE's Office of Heavy Vehicle Technologies (OHVT) is focusing its research in cooperation with industry partners on developing diesel engine technologies that can realize large fuel savings. Major diesel engine program milestones include the following.

Develop by 2002 enabling technologies to support large-scale industry dieselization of light trucks.
Develop by 2004 enabling technologies for class 7-8 trucks with fuel efficiency of 10 mpg that meet prevailing emission standards.
Develop by 2006 diesel engines with fuel flexibility and thermal efficiency of 50% with diesel liquid alternative fuels

- By 2005, develop advanced powertrain technology for medium/heavy-duty trucks that achieves up to two times today's fuel economy, also incorporating an alternative fuels use capability.

- DOE has contributed to a number of technological accomplishments relating to the development and deployment of cleaner and more efficient diesel engines:

- New prototypes of diesel engines for sport utility vehicles have been built and are undergoing evaluation in test cells as well as in vehicles. Fuel economy is expected to be more than 50% better than gasoline engines.
- The program has helped engine manufacturers to reduce NO_X emissions by over 50% and particulate matter by over 80% in production engines without after-treatment. New conceptual models of NO_x production during diesel combustion developed by DOE national laboratories are now used by industry.

- A new type of particulate filter has been developed through the prototype stage that removes over 80% of particulate emissions. Additionally, NO_x catalysts have produced a greater than 50% reduction of NO_x while plasma-assisted devices have exceeded 70% on a small scale.
- Engine efficiency of approximately 52% has been achieved in test engines, compared to 44% in production engines when the program began and 46% today.
- Alternative-fuel heavy-duty engines have been introduced and certified in numerous applications. These include natural gas engines for urban buses and alcohol-fueled engines for trucks and buses.
- LNG-powered trucks with 80% less NO_x and particulates than conventional diesel-powered vehicles have been demonstrated.
- A multi-cylinder heavy-duty diesel engine that runs interchangeably on M85 and diesel fuel has been developed and demonstrated.

Benefits and Costs

Benefits. Successful implementation of the OHVT 1998 program plan is key to "turning the corner" regarding the growth in truck-related fuel consumption. It is expected to reduce petroleum consumption of all classes of trucks by .1 million barrels of oil per day by 2010 and .2 million barrels of oil per day by 2020, amounting to a reduction of total highway petroleum consumption (including passenger cars) of 13.2% and 18.6% respectively. The reduction in projected petroleum use due to efficiency gains alone is estimated to be 552, 000 barrels per day by 2020, which is 8% of total highway petroleum use. This saving increases to 770,000 barrels per day by 2030. Petroleum use reductions due to market penetration of non-petroleum fuels are estimated to be 807,000 barrels per day by 2020 and 1.06 million barrels per day by 2030. From 1983 to 1998, increased efficiency in heavy diesel trucks reduced emissions of carbon by 38.2 million metric tons and saving 16 billion gallons of fuel, the equivalent of 2.18 quadrillion Btu. The cumulative economic value of increased efficiency is estimated at about $17 billion.

Increased Efficiency in Heavy Diesel Trucks

Gallons Saved (millions)	Time Frame	Btus Saved (Quadrillions)	Million Metric Tons Carbon Reducued
15,725	1983-1998	2.18	38.2

Costs. Reducing the pollution from diesel engines will require significant investments in new technology and in fuel reformulations. The DOE R&D investment in diesel engines from 1983 through FY 1997 totaled approximately $45 million.

The Big Picture

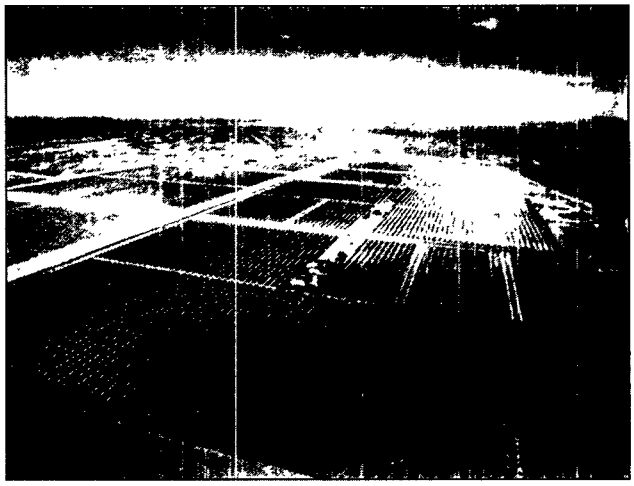
The health and continued growth of the U.S. truck economy depends on enhancing diesel fuel efficiencies and, therefore, profitability of the trucking economy. Class 1 – 8 trucks are the mainstay of U.S. trade, domestic commerce, and sustainable economic growth. Total highway freight transportation expenditures in 1995 were over $348 billion, accounting for 79% of the U.S. freight bill and about 4.8% of the GDP.

References

U.S. Department of Energy, Office of Heavy Vehicle Technologies and Heavy Industry Partners, *Multiyear Program Plan for 1998-2002*, August 1998 (DOE-ORO/2071).

Parabolic Troughs: Solar Power for Today

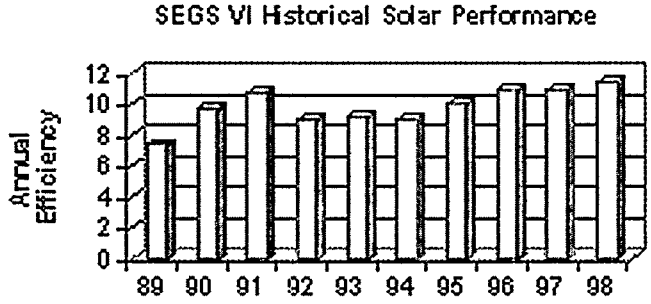
The lowest-cost solar power option available today is parabolic trough technology. These systems use curved mirrors to focus sunlight on a receiver pipe, heating the oil within it, producing steam and generating electricity. Parabolic-trough technology developed by DOE is being used in nine power plants known as the Solar Electric Generating Systems (SEGS) located in California's Mojave Desert. The plants have been operated as commercial peak power facilities since 1985 and sell their power to the local utility, Southern California Edison. The nine plants, which total 354 MW of installed capacity, generate enough power to meet the needs of approximately 500,000 people.



Aerial view of Kramer Junction in California

Benefits, Costs, and the DOE Role

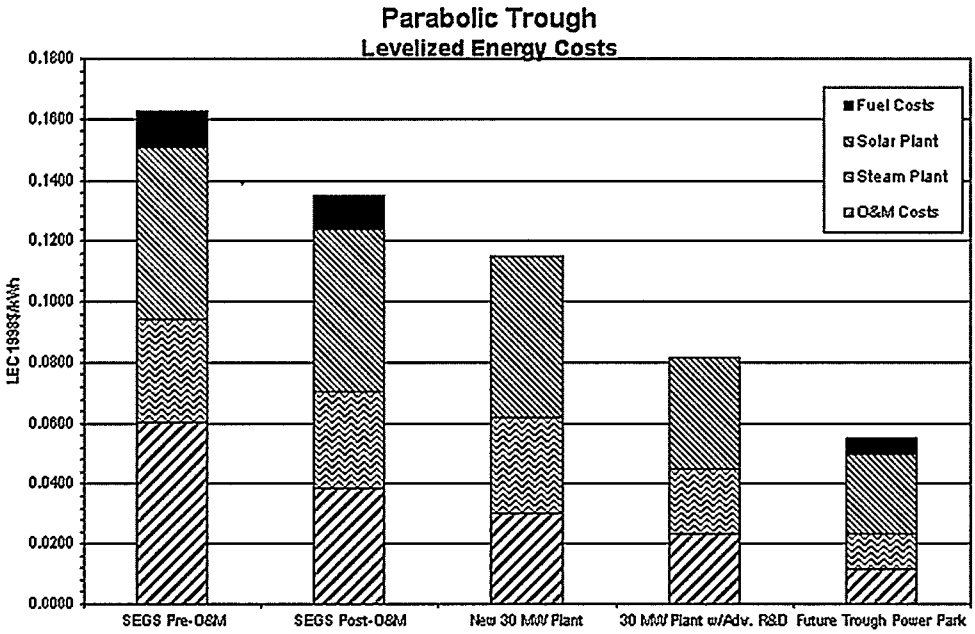
In 1992, DOE and Sandia National Laboratories initiated an operation and maintenance (O&M) cost-reduction study with KJC Operating Company (Kramer Junction), the operator of the SEGS III-VII plants. Through this six-year, $6.3 Million R&D effort (50/50 cost share), Kramer Junction and Sandia continued to advance parabolic-trough technology and helped reduce the O&M costs of these facilities by $4 million annually and $42 million (30%) during the remaining life of these projects. More impressively, the performance of the Kramer Junction plants has continued to improve over the last seven years. These five plants produced a record amount of solar electricity during 1998, with only average solar radiation. The figure below shows how the solar-to-electric efficiency of one plant (SEGS VI) has continued to improve over time. As these lessons begin to trickle down to the other SEGS facilities, their performance will improve as well.



Current O&M activities are centered on the evacuated receiver tube located at the focus of the parabola-shaped mirrors. Since these tubes are expensive, DOE and SunLab are working with the existing trough facilities to improve their durability. SunLab is a virtual laboratory integrating the concentrating solar power program efforts conducted by both Sandia and the National Renewable Energy Laboratory. During 1998, SunLab assisted Daggett Leasing (the operator of SEGS I and II) in developing a low-cost replacement receiver tube that will dramatically improve the performance of the SEGS II plant, with a payback of less than two years. This effort continued in 1999, leading to similar solutions for the SEGS I plant, which has an earlier-generation collector with different design issues. DOE/SunLab also has plans to work with Harper Lake (the operator of SEGS VIII and IX plants) to allow them to take advantage of these technology improvements.

The Big Picture: A Technology Path to Success

The figure below charts the actual reduction in levelized energy cost (LEC) resulting from DOE's O&M cost-reduction program in the early 1990s, from the projected reduction from DOE's new advanced-trough RD&D (research, development, and deployment) initiative, and from the future implementation of



troughs in a solar-power-park configuration.

SEGS Pre-O&M (1992) — Actual SEGS VI plant performance and O&M costs before the DOE/Sandia/KJC O&M cost-reduction program. The SEGS plants use 25% natural gas (fuel cost).

SEGS Post-O&M (1998) — Shows the benefit of DOE's O&M cost reduction program to SEGS VI. This includes performance improvements and O&M cost reductions.

New 30 MW Plant (2000) — The next trough plant is likely to be an ISCCS (integrated solar combined cycle system). In this case, the costs shown are only for the solar power. In these plants, the cost of solar power is higher than the averaged power cost.

30-MW Plant with Advanced R&D (2005) — An ISCCS plant reflecting the benefits of the trough activities during the next few years, primarily through enhanced performance and further cost reductions.

Future Trough Power Park (2010) — This is a large 200-MW SEGS plant built in a power park configuration. The cost reductions are primarily a result of building multiple (e.g., five) large plants. This scenario also assumes a production tax credit similar to REPI.

For More Information

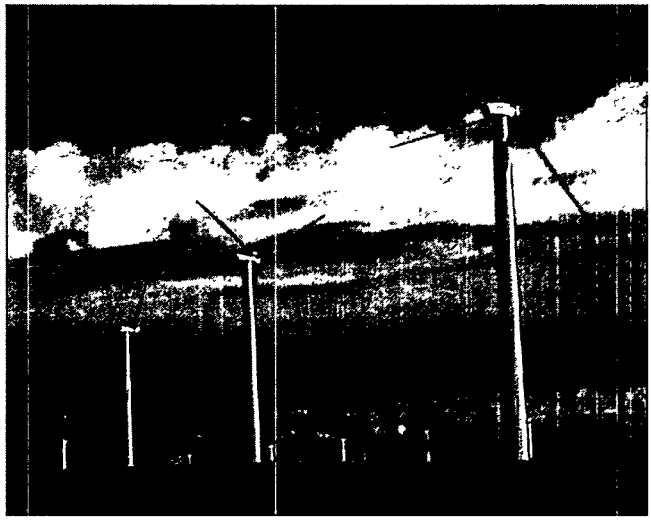
DOE's SunLab web site: http://www.eren.doe.gov/sunlab

Price, H. W., and D. W. Kearney, "Parabolic Trough Technology Roadmap," NREL, January 1999.

Cable, R. G., G. E. Cohen, and D. W. Kearney, "SEGS Plant Performance 1989-1997," *Proceeding of the ASME 1998 International Solar Energy Conference*, Albuquerque, New Mexico, June 1998.

Wind Turbine Advances

The fastest growing source of energy in the world during the 1990s is the same source that has been used for centuries to fulfill a variety of needs—wind. New wind-generating capacity grew by 2100 MW in 1998, resulting in a 25% increase in worldwide wind-generating capacity to nearly 10,000 MW. The renewed popularity of this universal and inexhaustible resource has been made possible by dramatic improvements in wind turbine technology over the last decade. Most of the new capacity is provided by "wind plants" featuring from one to over one hundred modern, high-tech wind turbines towering 30 to 70 meters above the ground, with blades sweeping out circles 40 meters or more across. Wind is also being put to use with smaller turbines in a wide range of applications.



Wind plant near Lake Benton, Minnesota

The DOE Role

Government-sponsored R&D in the United States and Europe has been key to helping the wind industry improve their technology. DOE is continuing to play a leading role in research that has yielded the sophisticated tools and expertise needed to design, build, and operate cost-competitive wind turbines. Further, DOE has helped U.S. industry put research breakthroughs to work through cost-shared partnerships that have produced world-class wind turbines.

Benefits and Costs

The 107-MW wind power plant shown above, located near Lake Benton, Minnesota, was the world's largest wind-generation facility at the time of its completion in 1998 by Enron Wind Corporation of Tehachapi, California. Electricity generated by this facility is sufficient to power 43,000 homes. Displacement of greenhouse gas emissions by this facility will be equivalent to removing 50,000 new cars and light trucks from the road. U.S. facilities totaling over 160 MW in generating capacity are using Enron Wind's 750-kW and 550-kW turbines and have generated 122 GWh of electricity (equivalent to 1.3 trillion Btu of primary energy). Over their lifetimes, the turbines will displace 110 trillion Btu of primary energy, save $246 million in energy costs, and reduce carbon emissions by 2.1 million metric tons. Enron Wind is currently underway in developing additional U.S. wind plants totaling over 300 MW in generating capacity.

> "The DOE Wind Program has been extremely helpful in accelerating our development of commercial wind turbines through advanced airfoils, blade testing, design codes, turbine load verification, assistance with value engineering, and much more."
>
> Kenneth C. Karas
> Chairman & Chief Executive Officer
> Enron Wind Corp.

Enron Wind's turbine manufacturing subsidiary, Zond Energy Systems Inc. of Tehachapi, California, was competitively selected to partner with DOE under its wind turbine research and field verification

programs for the development of the 550-kW Z-40, Zond's first commercial wind turbine and the predecessor to their 750-kW turbine. Under these programs, DOE was able to assist Zond with the latest wind turbine design methods and tools, provide blade structural and other testing services otherwise unavailable, and provide opportunities for Zond to gain valuable early field verification experience. The DOE contributions to the programs that supported Zond's 750-kW turbine since 1994 total nearly $12 million.

DOE has also partnered with Atlantic Orient Corporation of Norwich, Vermont, for the R&D leading to their AOC 15/50 turbine, rated at 50 kW. The AOC 15/50 is designed to be cost effective, rugged, and simple, at a size needed to serve a wide range of applications, from hybrid power systems for remote communities to grid-connected distributed power. Three of these turbines have been helping the utility serving Kotzebue, Alaska, reduce fuel consumption in their diesel power system since 1997, and installation of another seven turbines is planned for 1999. Other units are in operation in the extreme heat of the desert environment in Morocco. Atlantic Orient Corporation is now moving aggressively to supply orders for 30 more turbines over the next year.

Future Developments

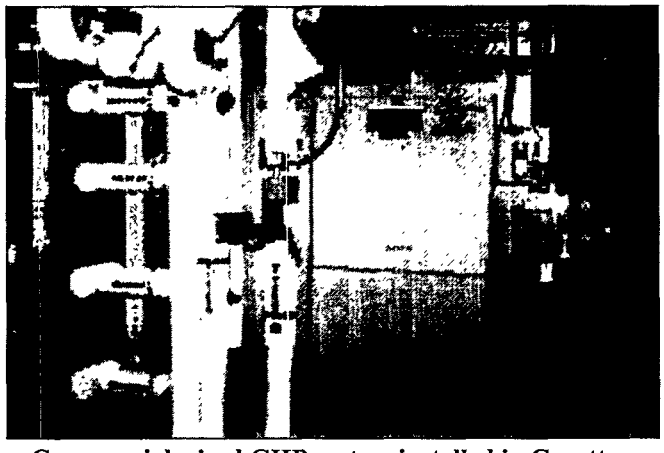
Even more advanced technology is on the way for the future. DOE is currently sponsoring a $50 million program to push the technology envelope further and develop the next generation of wind turbines, with 30% of these funds coming from private industry. These innovative, advanced turbines are targeted to produce electricity for 2.5 cents/kWh at good wind sites, which will make wind energy even more competitive with fossil generation sources in many locations around the world.

For More Information

DOE's Wind web site: http://www.eren.doe.gov/wind

Geothermal Heat Pumps

Geothermal heat pumps (GHPs) use the Earth to meet residential and commercial heating, cooling and hot water needs. The temperature of the Earth's crust is extremely stable just a few feet below the surface. Even extreme cold spells and extended summer heat waves have little effect on the ground's temperature three or four feet down. This temperature stability is the principle behind GHP technology. GHPs discharge waste heat to the ground during the cooling season and extract heat from the ground during the heating season.



Commercial -sized GHP system installed in Cavett Elementary School, Lincoln, Nebraska.
Ann Tundy, NREL/PIX06570.

The DOE Role

During the 1980s Oak Ridge National Laboratory and the International Ground Source Heat Pump Association (IGSHPA) conducted experimental and analytical studies of GHP systems for DOE. The primary focus of the effort was to develop a technology base to enable the design of systems with lower first costs to the consumer. In 1994, as part of the Climate Change Action Plan, DOE worked with the Edison Electric Institute, EPA, Electric Power Research Institute (EPRI), IGSHPA, National Rural Electric Cooperative Association, and industry to create the Geothermal Heat Pump Consortium. DOE has also supported research and development activities, especially through IGSHPA, the American Society of Heating, Refrigeration, and Air-Conditioning Engineers, the National Ground Water Association, and DOE's national laboratories. The work has targeted several areas of GHP technology, including improving on-site thermal conductivity testing, improving grouts, lowering the cost of ground heat exchangers, and developing advanced design software to determine appropriate sizing of GHP systems.

Benefits and Costs

Geothermal heat pumps are one of the most cost-effective heating and cooling systems available. A typical system can reduce energy consumption by 23 to 44% compared to traditional heating/cooling systems according to EPA. While GHPs are typically more expensive to install, their greater efficiency means the investment may be recouped in three to ten years. Experience has shown that use of GHPs can be beneficial to electric utilities and their customers. GHPs offer a flatter load profile (reduced "peaks and valleys") because they take advantage of the Earth's relatively constant ground temperature. The result is a smaller contribution to weather-related peak demand than other with electric options.

A highly successful shared energy savings project at Fort Polk, Louisiana, where 4,000 U.S. Army housing units were converted to GHPs, is a splendid example of this technology's electric utility benefits through load management. Statistically valid data indicated that Fort Polk achieved a reduction of 43%, or 7.5 MW, of peak summer load after installing GHPs and improved whole-house load factors from 0.52 to 0.62. Since the GHP systems were installed, service calls on hot summer days have dropped from 90

per day to just a few, testifying to the reliability of GHP systems. In February 1999 FEMP announced the selection of five contractors under the GHP-technology-specific super energy savings performance contracts to greatly increase private-sector investment and fund the installation of about 100,000 GHP units throughout the federal government.

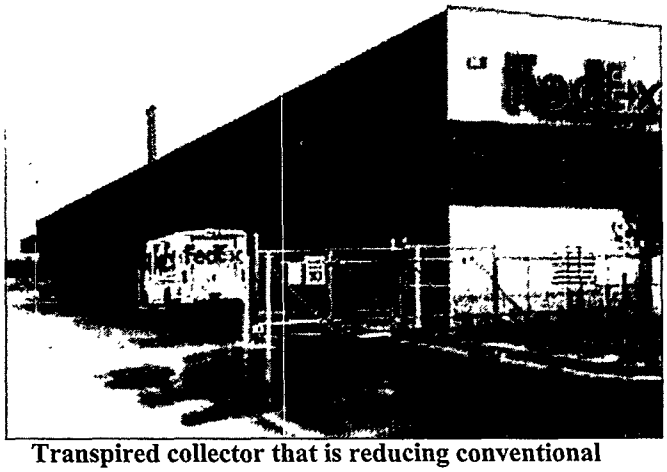
About 340,000 GHPs are being used for heating and cooling of residential, commercial, and institutional buildings throughout the United States today. Assuming average unit annual savings of $300 to $400, annual savings due to displacement of air-source heat pumps and other conventional equipment by GHPs is between $100 million and $140 million per year. Savings from GHP units intalled between 1995 and 1998 are estimated to be $29-$39 million. Over their lifetimes, the units will save 25 trillion Btu of energy, $980 million in energy costs, and reduce carbon emissions by 1.7 million metric tons. DOE funding for the GHP program has been approximately $24 million from 1995 to 1998, with another $35 million contributed by utilities.

For More Information

DOE's Geothermal web site: http://www.eren.doe.gov/geothermal.

Transpired Solar Collectors

Most industrial and commercial buildings require large quantities of ventilation air to maintain a healthful work environment. In many regions, this ventilation air needs to be heated throughout the fall and winter. Transpired solar collectors are a reliable, low-cost technology for preheating ventilation air. With simple payback periods from 3 to 12 years and an estimated 30-year life span, transpired collector systems offer building owners substantial savings.



Transpired collector that is reducing conventional heating loads at a Denver-area Federal Express facility.
Keith Gawlik, NREL/PIX04118

In a typical application, a large portion of a building's south-facing wall is clad with dark-colored, perforated metal sheeting, which performs as a large solar collector. The sheeting is mounted to the building's structural wall, creating a 4- to 6-inch gap between the two. As outside air is drawn through the collector's perforations by ventilation fans, its temperature increases by as much as 40°F. The heated air flows to the top of the wall, where it is distributed to the building's interior through conventional ductwork.

The DOE Role

Scientists at DOE's National Renewable Energy Laboratory (NREL) and engineers at Conserval Systems, Inc. independently developed the transpired collector concept in the late 1980s. With funding from DOE, NREL researchers conducted fundamental investigations into the collector's heat-flow characteristics and developed TCFLOW, a computer program used by Conserval to determine optimal airflow rates, plenum depth, and perforation sizing and spacing. With funding from DOE's Inventions and Innovations Program, Conserval installed the technology in an assembly plant and monitored its use. Through its Commercialization Ventures Program, DOE is partially funding the construction of a new manufacturing facility in Buffalo, New York, after banks indicated that they would only partially finance the facility. DOE and NREL are also continuing to provide technical support to Conserval.

Benefits and Costs

The transpired solar collector was developed jointly during the last decade by researchers at NREL, engineers at Conserval, and the Department of Natural Resources, Canada, through a cost-shared collaborative in which DOE provided $2 million in funding from 1990 to 1994. As a result of these efforts, the transpired collector is one of the most efficient solar collectors, converting as much as 80% (60 to 75% under typical operating conditions) of the solar energy striking it into usable heat. Flat plate collectors for domestic hot water applications typically have efficiencies of 35-40%. Conserval markets the technology as the Solarwall® and has installed more than 52 systems since 1992. Ford, General Motors, Federal Express, and McDonnell Douglas are on the growing list of industrial users of this technology. A typical system (6237 ft^2 of collector area) saves 1,665 million Btu per year. Current annual energy savings for the 52 installed systems is approximately 86,600 million Btu per year, saving

about $400,000 per year in avoided fuel costs, and reducing annual CO_2 emissions by 10 million pounds. Over their lifetimes, the currently installed systems will displace 2.2 trillion Btus of energy, save $10 million in avoided fuel costs, and reduce carbon emissions by 0.03 million metric tons.

Transpired collectors have caught the attention of the research community. In 1994 NREL and Conserval were jointly awarded R&D Magazine's prestigious R&D 100 Award for developing the technology, and Popular Science assessed the transpired collector as one of the 100 most important technology advances of 1994.

Potential Future Benefits

According to John Hollick, President of Conserval, "[transpired collectors have] the potential to be installed on the south wall of most new buildings and save enormous amounts of energy, which will help regions meet commitments to reduce emissions." Construction of the manufacturing plant in Buffalo could reduce installed costs by up to 40% with a 30-day reduction in turn-around time.

For More Information

DOE's Solar Buildings web site: http://www.eren.doe.gov/solarbuildings

FIELD VERIFICATION, DEPLOYMENT, AND OUTREACH SUCCESSES

Realizing the benefits of advanced technologies requires that they find their way into the marketplace so they can be used by consumers. Market forces determine which technologies make this transition to the market; however, major informational, financial, institutional, and infrastructure barriers must often be overcome in order for clean energy technologies to become a part of our over-all energy system.

The market of energy users is broad and diverse, including hundreds of millions of residential, commercial, and transportation users, hundreds of thousands of industrial users and millions of users in the power sector. To enable deployment of advanced energy technologies and practices, EERE works with the leadership of high leverage public and private organizations, such as States, universities, associations, unions, technology companies, utilities, and civic/community groups who have the direct constituencies, markets, and resources that can influence energy decisions.

In addition, DOE provides financial assistance and works with public- and private-sector officials to identify and remove barriers in government procurement systems, design and construction practices, financing practices, insurance practices, and in codes and standards.

A SAMPLE OF VERIFICATION, DEPLOYMENT, AND OUTREACH SUCCESSES

This section describes nine field verification, deployment, and outreach successes that have accelerated and expanded the use of efficient and renewable energy technologies.

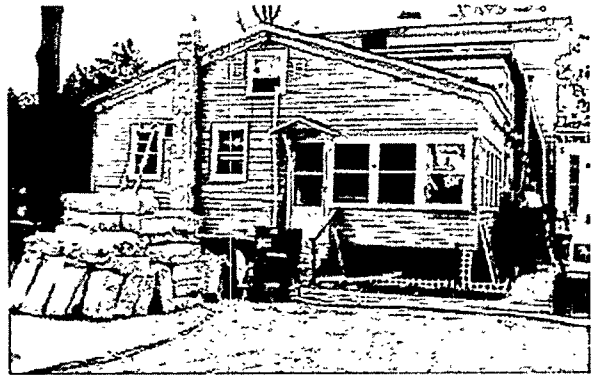
A Sample of Field Verification, Deployment, and Outreach Successes

Buildings	**Federal**
➢ Weatherization Assistance Program	➢ Energy Savings Performance Contracts
➢ Building Standards	
➢ Rebuild America	
Industry	**Transportation**
➢ Energy-Saving Technologies at Bethlehem Steel's Burns Harbor Division	➢ Clean Cities
➢ Industrial Assessment Centers	➢ Cellulose-to-Ethanol Program
➢ Motor Challenge	

Weatherization Assistance Program

DOE's Weatherization Assistance Program has long served as the nation's core program for delivering energy conservation services to low-income Americans. Low-income households spend about 14.9% of their income for energy needs, as opposed to the 3.5% of income spent on energy needs by other households. The Weatherization Program reduces this disproportionate burden. The program's resources are focused particularly on the elderly, persons with disabilities, and families with children.

The Weatherization Program is implemented through grants to State Weatherization Offices in all 50 states. These agencies allocate funds to about 950 local agencies, most of which are private, nonprofit community action agencies. Through these local agencies, the program has retrofitted 4.8 million homes since 1976. It is estimated that the average home weatherized in 1998 will save 32.2 million Btu of energy annually, and occupants will pay about $200 less in utility bills each year.



Powerful blowing machines make the job of installing cellulose insulation more efficient.

The DOE Role

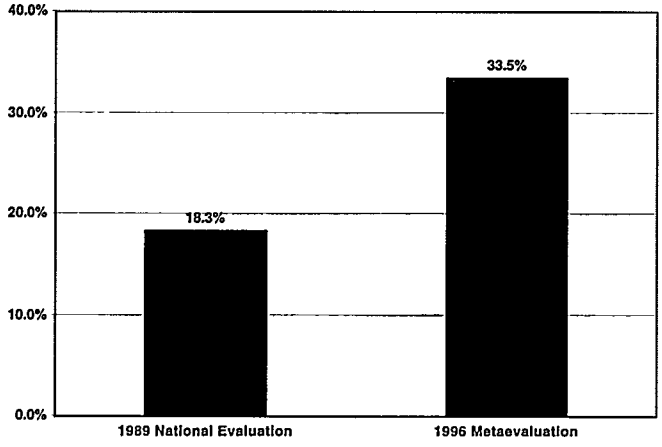
The Weatherization Program has served as the nation's core program for delivering energy conservation services to low-income Americans since it was created by Congress in 1976 under the Energy Conservation and Production Act. DOE funding is supplemented by state allocations of funding from the Low-Income Home Energy Assistance Program (LIHEAP—sponsored by the Department of Health and Human Services) and by resources leveraged from utilities, states, and other sources. The program is managed by the DOE Office of Building Technology, State and Community Programs. As the result of successful leveraging, DOE provided less than half (45%) of the resources spent on low-income weatherization between 1978 and 1996; the vast majority of those non-DOE funds are channeled through the program and are spent according to DOE's program rules.

The Weatherization Program grew out of the 1973 oil crisis, when state and community agencies began helping families conserve energy and save money, in many cases to keep them from having to choose between food and fuel. The program initially emphasized emergency and temporary measures such as caulking and weather stripping. By the early 1980s, the emphasis turned to more permanent and cost-effective measures such as installing storm windows and insulating attics. Program funding for efficiency improvements to existing space heating and water heating systems and replacement of defective furnaces and boilers was first allowed in the mid-1980s. Regulations adopted in the 1990s ensured further energy and cost savings by extending the program to cooling technologies in warm climates, where cooling costs are higher than heating costs.

Since the early 1990s, the program has been further improved by better training, better management practices, and various technical advances, with little increase in cost. DOE funding has enabled Oak Ridge National Laboratory to develop the National Energy Audit (NEAT), which selects cost-effective energy conservation measures specifically for each house. NEAT is currently being used by approximately 500 local agencies in 31 states to make retrofitting decisions for more than 80,000 low-income dwellings every year.

Benefits and Costs

A 1990 evaluation of the Weatherization Program found that the program was meeting the objectives of its enabling legislation by (1) saving energy, (2) lowering fuel bills, and (3) improving the health and safety of low-income households. Installation of energy conservation measures, including overhead and management, cost an average of $1550 per house. The annual energy savings for a home weatherized in 1989 was estimated to be 17.6 million Btu, producing an energy savings of $1690 over the 20-year lifetime of the weatherization measures. For homes heated with natural gas, weatherization reduced natural gas consumption for space heating by 18.3%.



By 1996 program costs rose 12% with inflation adjustments to $1700 per home, but the program was achieving 80% higher average savings per dwelling than in 1989, according to a 1996 metaevaluation of 17 state-level evaluations. The study suggested that improving program practices between 1989 and 1996 increased average savings to 33.5% of natural gas space heating consumption. Assuming that this same level of improvement was achieved in homes heated by other fuels, the annual energy savings for a home weatherized in 1996 is estimated to be 32.2 million Btu. Over the 20-year life of the weatherization measures, this represents an energy cost savings of more than $3000 per house.

Weatherization of low-income homes directly and immediately improves the health and safety of inhabitants by reducing carbon monoxide emissions and eliminating fire hazards, in addition to lightening the financial burdens of those most in need. The program's longer-term impacts include community revitalization. The Weatherization Program has also created about 8,000 jobs nationwide; 52 jobs grow directly from every million dollars invested in the program.

DOE's 1998 budget of $125 million leveraged an additional $198 million to weatherize 167,400 homes. Over the 20-year life of the weatherization measures, these homes will save 108 trillion Btu of energy, their occupants will pay $550 million less in utility bills, and 1.63 MMTC of carbon emissions will be averted.

The Big Picture

The Weatherization Program is accomplishing its primary mission by providing a program that significantly decreases energy use in low-income homes. Although five million homes have been weatherized since the program's inception, the largest part of the task still remains. Nearly 28 million households are federally eligible for weatherization assistance.

For More Information

http://www.eren.doe.gov/buildings/state_and_community/weather/

Berry, Linda G., Marilyn A. Brown, and Laurence F. Kinney, Progress Report of the National Weatherization Assistance Program, Oak Ridge National Laboratory, Report ORNL/CON-450, 1997.

Building Standards

States with energy codes require that all new houses and new commercial, industrial, and high-rise residential buildings achieve at least a minimum level of energy efficiency that is cost-effective and technically feasible. Since 1980, DOE's Building Standards and Guidelines Program (BSGP) has worked with a variety of partners to improve the design and implementation of these codes. BSGP provides information and a comprehensive line of support tools to help builders, designers, and code officials to comply with energy codes.

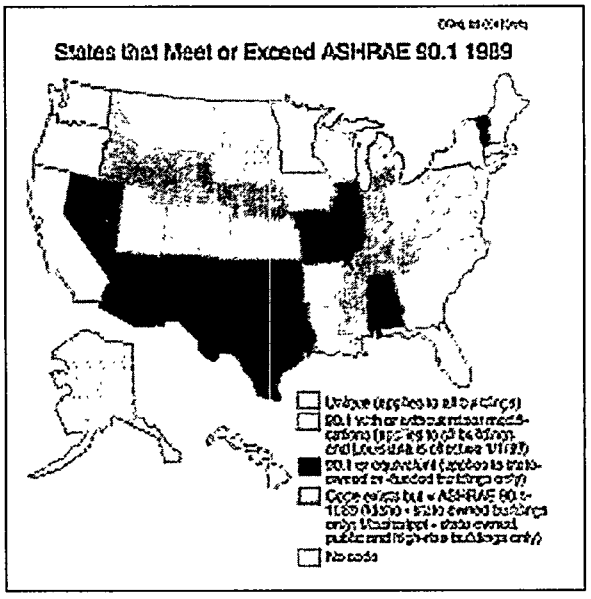
The DOE Role

The Building Standards and Guidelines Program takes a comprehensive approach and works with a wide range of organizations to achieve its goals. Collaborators include DOE Regional Offices, state energy agencies, model code and standards organizations, public interest groups, and a variety of industrial partners. DOE, in collaboration with these partners, has accelerated the implementation of building codes in many states by providing technical support, DOE State Energy Program grants, and other BSGP services such as an information hotline, a web site, national building codes conferences, and a newsletter.

Through its outreach activities, DOE has provided direct technical support in the form of training, software development, analysis and research, advocacy, and materials development to 42 states and has created qualified energy code instructors in 32 states. Since 1994, BSGP has responded to over 12,000 support calls from code users and distributed over 23,000 copies of code compliance materials.

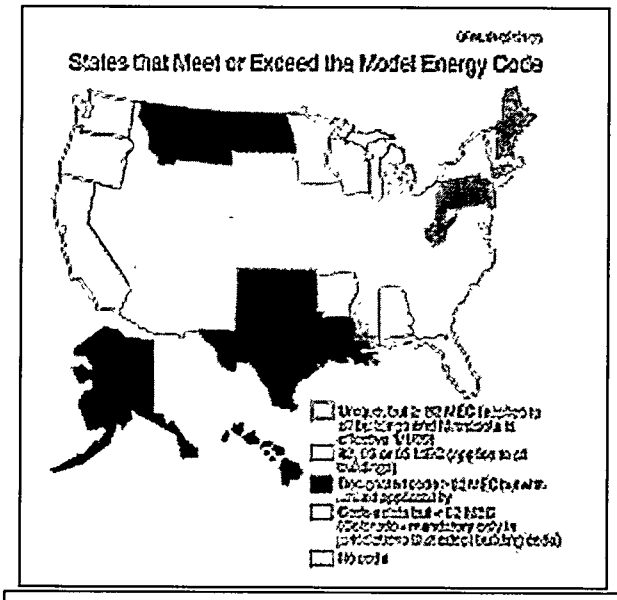
DOE has produced and widely disseminated MECcheck™, a software tool released in 1994 to simplify and improve code compliance. MECcheck helps designers, builders, code officials, and others in the building industry to comply with the Model Energy Code (MEC) for residential buildings. MECcheck materials include a comprehensive set of support tools, which combine simplified code requirements, easy-to-use software, and a consolidated workbook with prescriptive compliance tables, plus videos and training materials.

BSGP sponsors MECcheck training classes and periodic train-the-trainer sessions. The National Association of Home Builders incorporated MECcheck into their MEC Manual in early 1996. Twelve states currently distribute MECcheck to their code users. DOE estimates that MECcheck is used by at least 35,000 builders and code officials.



DOE has provided extensive energy code training using a variety of methods, including delivery via satellite broadcast and computer-based training tools. More than 1,000 individuals have attended.

DOE-supported training courses, and more than 250 individuals have participated in a train-the-trainer program that focuses on developing qualified MECcheck and COMcheck trainers.



With DOE assistance, almost two-thirds of new U.S. construction is now built in jurisdictions where new buildings must meet or exceed the 1992 Model Energy Code or ASHRAE/IES Standard 90.1-1989. Since 1992, about 350,000 additional housing units and over 50 million square feet of additional commercial floor space are being required to meet these relatively stringent energy codes each year.

Benefits and Costs

The benefits achieved from energy code upgrades through 1998 are shown in the following table. These savings are the result of energy code development, adoption, and support activities of DOE and its numerous private- and public-sector collaborators. The estimates are based on current adoption of state energy codes, and they assume that roughly half of the potential energy savings are actually realized. Thus, the estimates recognize that code compliance and enforcement are imperfect and that actual energy performance is not as energy-efficient as rated performance. Even with this conservative assumption, consumers nationwide saved around $1.1 billion in 1998, equivalent to about 1% of total energy expenditures for space heating and cooling in all buildings, as a result of the adoption and implementation of improved energy codes. These savings are limited in part by the slow turnover of the nation's building stock. The savings will automatically grow over time as more buildings are constructed and more jurisdictions adopt state-of-the-art codes.

Benefits of Residential and Commercial Building Energy Codes in 1998

Primary Energy Savings	154 TBtu
Energy Cost Savings	$1.12B (1994$)
Carbon Reductions	3.55 MtC

The BSGP has operated since 1980. The program's budget in 1998 was $8 million per year. Assuming steady funding from 1980 through 1998, the cumulative DOE investment has been $144 million. Approximately half of this budget goes to state agencies through DOE's State Energy Program.

For More Information

http://www.energycodes.org/

Geller, Howard and Jennifer Thorne. 1999. "U.S. Department of Energy's Office of Building Technologies: Successful Initiatives of the 1990s." American Council for an Energy Efficient Economy: Washington, D.C.

Rebuild America: Catalyzing Community Networks

DOE's Rebuild America program aims to accelerate the adoption of energy-efficient techniques and practices in commercial, institutional, and multi-family residential buildings. The network of over 250 community partnerships that it has created involves local governments, schools, housing agencies, and private businesses. Each partnership is unique; each has its own motivations (affordable energy, environmental quality, community development, job creation, or school improvement); and each community sets its own goals. Altogether, these partnerships are pursuing energy-efficient retrofits of more than 800 million square feet of commercial floorspace.

The DOE Role

The program supports the partnerships with a national network of technical and business experts, resource materials, and access to innovative solutions. Initial seed money for showcase partnerships is provided to allow continuing state involvement, and a program representative is assigned to coordinate technical assistance to the partnerships. This representative works with Rebuild America resources to teach communities about financing options and sources of technical expertise. These resources include guidebooks, technical experts, software, training and workshops, peer-to-peer exchange networks, and referrals to companion programs. By providing business and technical tools and customized assistance to partnerships, DOE leverages local resources to the benefit of America's communities. Rebuild America then promotes its partnerships and recognizes their leaders locally, regionally, and nationally.

Some partnerships have leveraged as much as $25 million or more in private investment for their projects. They have also partnered with national financial institutions and federal empowerment/enterprise zones, used municipal bond issues, revolving loan programs, and historic preservation tax credits, and tapped commercial industry to fund projects. By 2003, Rebuild America communities will have generated $3 billion in private community investment and created 26,000 new jobs. Many Rebuild America partnerships have found that energy improvement in buildings can help them address other community needs, such as business development, economic revitalization, better education and housing, and resource conservation.

Partnerships' projects vary widely in size and scope, from simple lighting retrofits to statewide programs that include comprehensive building energy audits and retrofits and ongoing energy management and conservation programs. Building systems improvements can include energy-efficient lighting, heating and cooling equipment, windows, and ventilation systems, to name a few. Partnerships also get advice on energy audits, indoor air quality, renewable energy, building commissioning, performance contracting, measurement and verification, and other energy-related issues.

Benefits and Costs

Rebuild America is fostering community partnerships from rural Alaska to downtown Atlanta to Guam, with 33 state energy offices active in the program. Cities, counties, and states have initiated local partnerships with business owners, community leaders, utilities, school administrators, nonprofits, and economic development organizations to accomplish building renovation projects. With approximately over 250 partnerships having committed over 800 million square feet of building space for renovation, Rebuild America is well on its way to exceeding its goal for 2003: over 250 communities committing two billion square feet of floor space to energy retrofits. That means Rebuild America will save $650 million dollars in energy costs per year and reduce air pollution by 1.6 million tons of carbon dioxide annually. At

Rebuild America is benchmarking schools in Ohio and other states.

one-fourth of its goal, estimates of benefits in 1999 are 32 trillion Btu of saved energy, $162 million in energy cost savings, and 0.4 MMTC of carbon dioxide emission reductions.

Rebuild America partnerships are giving older buildings a new lease on life with new technology and are helping business people, universities, school districts, arts and cultural organizations, and public agencies save 20 to 30 percent on their energy bills. Partnerships are encouraged to set energy conservation goals of at least 25 percent. The money saved can be put to work back in the community – buying computers and books for schools, revitalizing decaying down-towns, and protecting the environment.

Partnerships are now at work in 46 states, within several Native American tribes, and in two U.S. territories. For example:

- Building Owners and Managers of Atlanta, Inc., has targeted 30 million square feet of commercial office and retail space for renovation.
- The Portland Energy Office has completed retrofits on 35.8 million square feet.
- Rebuild Idaho has audited one million square feet in the Idaho Falls School District and saved one school $12,000 in 10 days during a vacation shutdown demonstration in 1998. The total weather-normalized savings to date for the school district is $45,000.
- Rebuild Webster City, Iowa, has retrofitted 20 buildings, including several schools, municipal buildings, churches, and private businesses, by leveraging a small amount of federal funding (less than $50,000) into nearly $5 million in energy efficiency improvements.
- Bob Housh, Project Director of EnergyWorks Rebuild America partnership in Kansas City, Missouri, estimates that his project has "identified over $2.5 million in annual savings in about 6.5 million square feet of space."

DOE has invested about $7 million in R&D and technical assistance through Rebuild America since the program's inception in 1995.

For More Information

http://www.eren.doe.gov/buildings/rebuild/

Energy Savings Performance Contracts

Energy savings performance contracts (ESPC) are a type of contract used by DOE and other federal agency energy management programs to cut government energy use and improve federal building energy efficiency. Authorized by the Energy Policy Act of 1992, ESPCs provide financing that is an alternative to federal appropriations. Federal agencies contract with private energy services companies to install and operate the innovative and energy efficient technologies and processes of the private sector with little up-front government money. As of 1998, 30 ESPC and Super ESPC projects were awarded by federal agencies. Currently, there is about $450 million in potential projects under the Super ESPCs. Super ESPCS were put in place by 1999 that have a total contract authority of over $6 billion. If the maximum authority of the contracts is used, the resulting contract value of the projects will reduce federal energy bills by $10 billion over their lifetimes, providing the federal government with funds that can be used for other priorities. The projects will also reduce carbon emissions by 2.8 million metric tons, and avoid the emission of 28,000 metric tons of NO_x and 49,000 metric tons of SO_2.

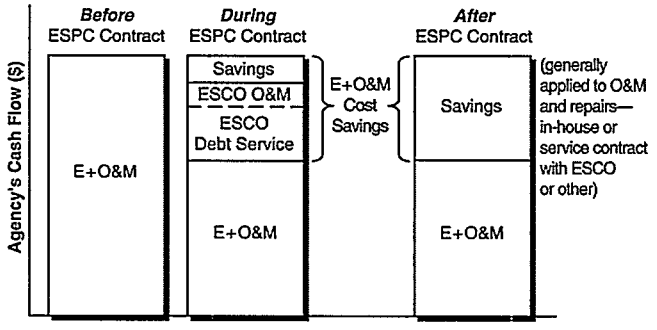
The DOE Role

The DOE Federal Energy Management Program promotes alternative financing methods to implement energy efficiency and renewable and emerging technology projects through the use of ESPCs and regional and technology-specific Super ESPCs. FEMP's FY1999 budget allocated $8.2 million to support the FEMP Service Network and to provide guidance and assistance to customers of ESPCs and other alternative financing such as utility energy services contracts.

FEMP actively promotes the use of ESPCs and Super ESPCs by placing information on its website, by providing TeleFEMP, broadcasts that detail the benefits of ESPCs, and through the national FEMP Service Network workshops and technical assistance. As part of the continuing evolution of the ESPC, DOE FEMP and the Department of Defense have recently simplified the ESPC process to make it more accessible to a wider range of federal organizations.

ORNL 99-06432/rra

ESPCs Reallocate the Federal Customer's Payments for Energy and Energy-Related Operations & Maintenance Expenses (E + O&M)



In the ESPC process, an energy services company upgrades existing processes or installs new equipment. The contractor guarantees a fixed energy cost savings over the life of the contract and is paid directly from those cost savings. Federal agencies retain the remainder of the energy cost savings, for themselves. Currently, federal agencies receive, on average, $2 in savings for every $1 in contractor investments.

Super ESPCs simplify the process of implementing an energy services contract. Super ESPCs are regional or national agreements that the government has made with energy services companies who have competed for the contracts and demonstrated their experience and qualifications. Federal agencies can place delivery orders against these "indefinite-delivery, indefinite-quantity" agreements, customizing the agreement to their own site-specific requirements. This allows agencies to cut the time and effort required to implement an ESPC with an energy service company to complete the order at least in half.

Benefits and Costs

One example of the benefits of ESPC agreements is in Hanford, Washington. One year after the Department of Energy's Richland Operations Office awarded an energy savings performance contract (ESPC) of unprecedented size, the department began two decades' worth of reduced energy consumption and more than $108 million in savings. The Hanford ESPC was facilitated by guidance and monetary support from FEMP.

In March 1997, DOE's Richland Operations Office awarded energy services provider Johnson Controls a 25-year, $160.3 million contract to replace the two central heating plants with 42 state-of-the-art steam production units located at 28 sites across Hanford; install a fully automated system to control operation of the package boilers; upgrade the World War II-era steam distribution system; and redesign the HVAC system. Under the terms of the ESPC, the Department of Energy will realize annual savings of approximately $4.32 million over 25 years.

Hanford's new, highly efficient boilers, fueled with natural gas and low-sulfur fuel oil, are designed to operate at efficiencies greater than 83%, compared to the 33% efficiency of the old central heating plants, and to consume 30% less fuel. NO_x and SO_2 emissions will be cut by as much as 95%, or 800 tons, per year and 5 million gallons of water will be conserved annually. Preliminary project validation efforts indicate that savings will range from 55 to 91% of the energy that would have otherwise been consumed—approximately 198 to 327.6 billion Btu.

Other examples of the significant benefits to be reaped from conventional ESPC and projects conducted under a Super ESPC are:

- In September 1998, the EPA's National Vehicle and Fuel Emissions Laboratory in Ann Arbor, Michigan, awarded an $8.5 million ESPC to overhaul its facilities. Annual energy costs at the Laboratory will be slashed from $1.08 million to approximately $368,000, and its annual energy consumption levels will be cut by 66%.

- On June 8, 1998, the initial Super ESPC delivery order was awarded for the U.S. Coast Guard for upgrades to its Integrated Support Center in Kodiak, Alaska. ERI Services, Inc., will invest $954,353 in energy-efficiency measures. The government anticipates annual savings of $228,824 and 662,000 kilowatt-hours over the seven-year delivery order term. Fuel oil consumption will also be cut by more than 135,000 gallons per year

- On February 22, 1999, the National Aeronautics and Space Administration utilized the Central Region Super ESPC to contract with Honeywell to install energy-efficient lights and compressed-air systems, reduce water consumption, and improve air conditioning controls at three facilities. The 23-year contract value of $43 million is expected to provide NASA with energy and operational cost savings of approximately $2 million per year.

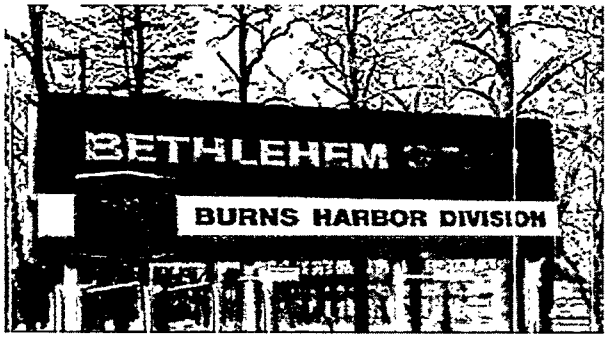
For More Information

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, "Energy Savings Performance Contracting Overview," available at http://www.eren.doe.gov/femp/financing/espcoverview.html

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, *FEMP Focus Newsletter*, June 1997, available at http://www.eren.doe.gov/femp/newsevents/femp_focus/jun97_awards.html

Bethlehem Steel's Burns Harbor Division

Bethlehem Steel Corporation recently joined with the Department of Energy's Office of Industrial Technologies to showcase energy saving technologies for the strategically important steel sector. To remain competitive in the global marketplace, U.S. steel producers must consistently reduce production costs while improving the quality of their products. A critical component of lowering overall production costs is reducing energy consumption during production.



The focus of the co-funded Bethlehem Steel (BSC) and Office of Industrial Technology (OIT) partnership was to slash energy costs at BSC's Burns Harbor, Indiana, steel mill through application and installation of advanced process technologies. It is estimated that if the six technologies and processes implemented at Burns Harbor were implemented throughout the steel industry, net energy savings by 2005 will be over 93 trillion Btu per year, the equivalent of over $198 million. In April 1998, steel industry decision-makers attended the DOE-organized Bethlehem Steel Energy Technology Showcase, which offered attendees an unusual opportunity to learn about these and other emerging steel technologies that can save energy, reduce emissions, and increase productivity.

The DOE Role

The Office of Industrial Technologies has been successful in lowering barriers to industry adoption of new processes and technologies by partnering with firms such as Bethlehem Steel Corporation. These partnerships demonstrate to other firms that the benefits of adoption outweigh the costs, and have allowed DOE to cost-share research and development of several of the innovative processes and technologies that were installed at Burns Harbor:

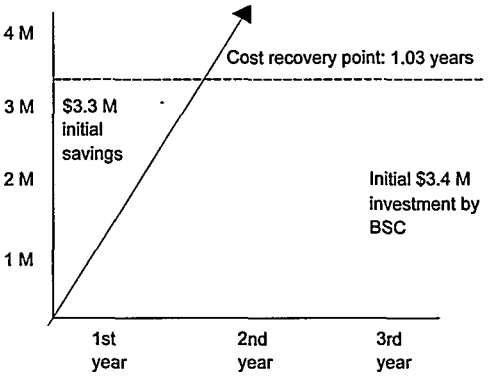
- Steam boiler system retrofits were conducted under the auspices of the Steam Challenge, a public-private partnership established by OIT and the Alliance to Save Energy.
- Optimization of induced draft fans in the basic oxygen furnaces (BOF) was part of an OIT Motor Challenge Showcase Demonstration.
- Installation of Sandusky International nickel aluminide steel rolls was made possible in part by nickel aluminide research funded by the OIT Advanced Industrial Materials Program.
- Installation of a Praxair oxy-fuel fired furnace combustion system was preceded by technology development funded by a grant from OIT's NICE3 Program.
- Adoption of the blast furnace granulated coal injection process was made possible by proof-of-concept research funded by DOE's Clean Coal Technology Program.
- Galvanneal advanced temperature measurement sensors and an oscillation combustion system, R&D funded in part by OIT's Industries of the Future Steel program.

Benefits and Costs

Financial and energy savings of $8 million and 2 trillion Btu will be realized at Burns Harbor. This includes enhancements made to the facility's steam boiler system that resulted in annual saving of some

40,000 megawatt-hours of electricity and 85 billion Btu of natural gas. Steel making at Burns Harbor requires large amounts of electricity that is produced by six steam turbines. To improve energy efficiency, the project focused on redesigning a turbine during scheduled maintenance periods, increasing the efficiency and electrical output under normal operations from 42 to 48 megawatts. Improving steam turbine performance at Burns Harbor resulted in first-year direct cost savings of $3.3 million. The direct investment for the steam turbine technology upgrade was only $3.4 million more than the cost of a standard maintenance overhaul.

Nickel aluminide steel rolls installed in the facility's annealing furnace save 300 billion Btu ($636,000) per year. The advanced material provides high strength and long life in hostile manufacturing environments, decreasing downtime and saving energy.



Fans, combustion systems, and sensors were also instrumental in energy and cost savings. Optimization of BOF draft fans is saving 15,500 megawatt-hours per year, working out to annual cost savings of more than $620,100 per year. The granulated coal injection process saves about 1.2 trillion Btu ($2,544,000) annually. Burns Harbor's new oscillating combustion system saves 260 billion Btu ($551,200) per year and lowers NO_x emissions, while the oxy-fuel-fired slab heating furnace combustion system saves 112 billion Btu ($237,440) per year. And the newly installed galvanneal temperature measurement sensor saves 100 billion Btu ($212,000) worth of energy per year.

The Big Picture

Assuming full market penetration of the technologies and processes demonstrated at the Burns Harbor Division, the domestic steel industry stands to reap net energy savings of 93.5 trillion Btu in 2005: 12.4 tBtu from the nickel aluminide steel rolls, 1.8 tBtu from the basic oxygen furnaces (BOF) fans, 77 tBtu from the Praxair oxy-fuel fired combustion system, 1.3 tBtu from Galvanneal temperature measurement sensors, and 1 tBtu from the oscillating combustion system. Energy cost savings of $198 million would result.

In addition to financial costs savings resulting from greater energy efficiency, the performance improvements from just two of the technologies, the nickel aluminide steel rolls and the oxy-fuel fired combustion system, result in significant industry-wide annual emissions reductions: Carbon dioxide (CO_2) - 1.2 million tons (297,818 MMTCE); Oxides of nitrogen (NO_x) - 4390 tons; Sulfur oxides (SO_x) - 8100 tons; Volatile Organic Compounds (VOCs) - 47 tons.

For More Information

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *OIT Times*, "OIT joins Bethlehem Steel, Alliance to Save Energy in showcasing energy saving technologies for industry," Summer 1998, available at http://www.oit.doe.gov/oittimes/sm98/98smpg1.shtml

http://www.oit.doe.gov/steel/

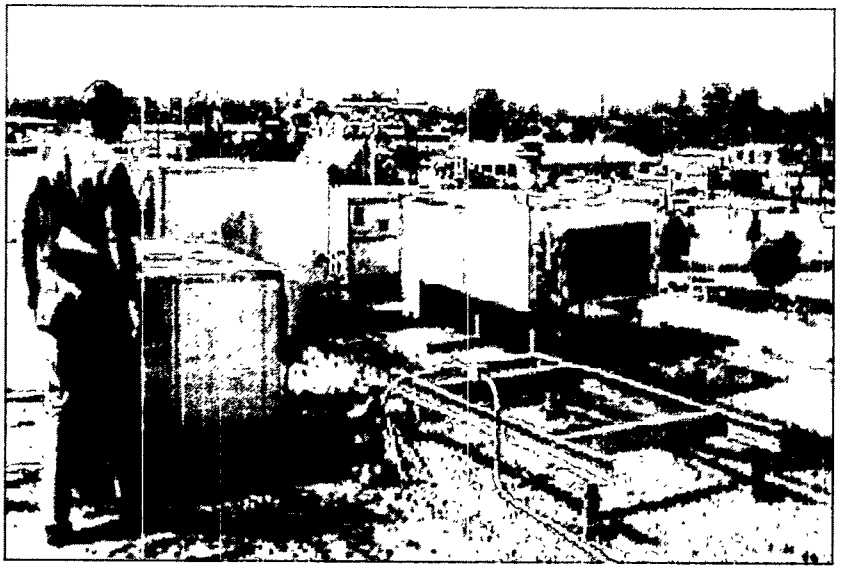
Industrial Assessment Centers

The Department of Energy's Office of Industrial Technologies has funded Industrial Assessment Centers (IACs), formerly known as Energy Analysis and Diagnostic Centers, since 1976. These IACs conduct successful, energy-saving industrial assessments of small- and mid-size manufacturing facilities. Through 1997,

- More than 7,600 audits have been completed.
- Audits recommended plant modifications with annual savings of more than $470 million (in 1997 dollars) and energy conservation exceeding 83 trillion British thermal units (Btus).
- Almost 40% of the recommendations and suggestions generated by IAC audits have been accepted and acted on by industrial firms.
- OIT has spent $46,787,000 on the program which has led to plant modifications with the potential to save industry more than $1.575 billion, better than a 7:1 total benefit to cost ratio.

The DOE Role

IAC industrial assessments, conducted by university engineering students under the guidance of trained faculty members at 30 participating schools, involve a thorough examination of the potential savings from energy efficiency and conservation improvements, waste minimization and pollution prevention, and productivity improvement. Assessments include pre-visit analyses, site visits and collecting engineering measurements. The team then performs a detailed analysis, generating specific recommendations with related estimates of costs, performance, and payback periods.



Site visits, as shown here, are an important component of the success and utility of IAC assessments.

The IAC program is designed to reach out to small and medium-sized manufacturers that don't necessarily possess the in-house expertise or funds for energy-related projects that larger manufacturers may have available to them. Energy costs are often a larger portion of total expenses for these small and medium-sized firms, thus IAC assessment-identified savings can have a considerable effect on the competitiveness of these firms.

Benefits and Costs

The estimate of energy savings given 40 percent of the IAC recommendations are implemented is conservative. The realization rate, that is, actual energy savings compared to estimated (recommended) savings, could be higher than 40 percent. Data from seven isolated studies performed by individual IAC's found implementation rates for energy-conservation recommendations between 48 and 65 percent. The average realization rates for demand side management energy conservation programs is 0.94 to 1.0, based on a review by Oak Ridge National Laboratory of many studies of these programs.

Although the details from assessments are held confidential, several projects' findings have been released, illustrating the success of this program and the benefits to be realized from implementing recommendations. An IAC assessment of a plastic cup (expanded polystyrene) factory made many recommendations, including the following:

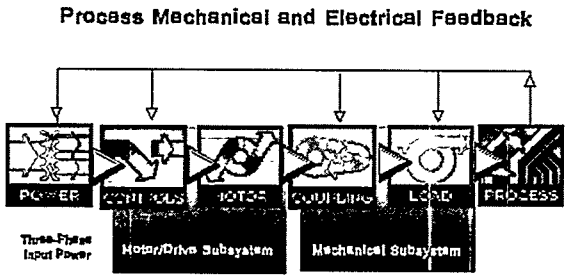
- Relocating air intakes allows compressors to operate more efficiently and with greater available capacity, resulting in potential energy and maintenance cost savings of $17,000 per year and an increase in profits, through increased production, of $65,000 per year.
- Replacing a compressed air product transport system with blowers could save $20,000 per year in energy costs.
- Using engineered nozzles to replace inadequate orifice fittings has the potential to provide an energy cost savings of $35,000/year.
- Making changes to the production line, such as replacing the compressed air system with a mechanical system to remove cups from molds, would save $130,000 per year in warehouse leasing costs.

Other examples of successful IAC projects include an assessment of a bottlemaking facility that returned energy savings and productivity recommendations with the potential to save $400,000/year, and an assessment at a tire manufacturing facility that implemented IAC-recommended modifications, realizing an additional $2.4 million in sales while reducing energy consumption. DOE estimates the IAC Program will save industry 71 tBtu and $300 million annually by 2000 while reducing carbon emissions by 1.51 MMT.

For More Information

For more information, please visit the IAC homepage at http://www.oit.doe.gov/iac/

Motor Challenge

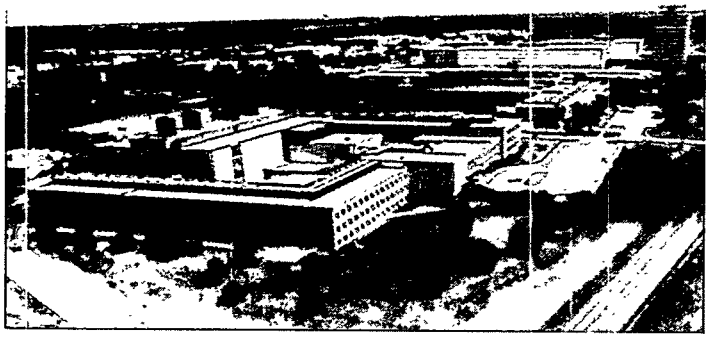


DOE's Motor Challenge program is an industry/government partnership that works to increase the market penetration of energy-efficient motor-driven systems. These systems reduce energy demand, lower emissions, and assist industry to maintain its competitiveness. A key element in the Motor Challenge strategy is to encourage a new "systems approach" to how motors, drives and motor-driven equipment are engineered, specified, and maintained by industry. Funded at $6.23 million in FY1998, Motor Challenge aims to help industry realize electricity cost savings of $370 million per year based on present electricity costs. Energy savings from just 13 demonstrations are 131 trillion Btu per year, or almost $2 million per year in cost savings.

The DOE Role

Motor Challenge is a network of resources that supplies free, unbiased, reliable information tailored to help industrial partners make key decisions about motor system purchasing and design. Motor Challenge services include:

- The Information Clearinghouse, which handles roughly 35,000 requests for information per year, serves as a one-stop shop for Motor Challenge information, tools and resources,
- The National Technical Assistance Service provides industrial partners access to the Clearinghouse engineering staff to gain insights concerning possible solutions to problems faced at their facilities,
- MotorMaster and ASDMaster software packages and related training materials assist users in selecting and operating energy-efficient motors and adjustable speed drive systems.
- Partnerships with original equipment manufacturers (OEM), trade associations, industrial entities, and utility companies to identify opportunities for highly-leveraged joint development of new tools and information and disseminate these to industrial end-users.



In May, 1995, Minnesota Mining and Manufacturing (3M) and the Office of Industrial Technologies joined forces to conduct a Motor Challenge Showcase Demonstration project at 3M Center, the company's corporate headquarters and research and development campus. The Demonstration examined energy consumption at a campus building, viewing the individual building as a distinct entity within a larger whole. Specific equipment upgrades or replacement decisions at 3M were based on financial and operational objectives, and implemented projects were intensively measured and monitored to compare actual savings

to predicted savings. DOE provided analysis tools that broadened the scope of the energy projects and guidance on what to measure before and after the retrofits.

Four improvements suitable for in-depth study were identified by the Demonstration methodology developed for use in Building 123. Upgrading the air and water supply systems and retrofitting energy-efficient motors resulted in the following savings:

- 41% reduction in electricity consumption from four upgrades
- Annual savings of $77,554 on a $79,499 investment (including demand-side management incentives provided by the local utility); giving a payback period of 1.03 years
- Annual emission reductions of 1.2 million tons of CO_2, 2,900 pounds of SO_X, 3,400 pounds of NO_X, 240 pounds of TSP, and 33 pounds of VOCs

3M Center is a large, complex campus (approximately 1000 electric motor systems serve the 7.5 million square foot headquarters). Applying the lessons learned from Building 123 to other campus facilities offers tremendous projected savings opportunities shown in the table below.

Benefits and Costs

Industrial motor systems represent the largest, single, electrical end use in the American economy—25% of the Nation's electricity consumption. Using proven, cost-effective technologies today can save manufacturers approximately 11 to 18% of current annual motor system energy usage (75 to 122 billion kWh), which would result in savings ranging from $3.6 to $5.8 billion annually. The energy and cost savings from just 13 demonstration projects, including the 3M campus discussed above, without any replication throughout industry, are almost $2 million per year as shown in the table below.

Demonstration Partner	Type of Plant	Energy Savings kWh/Year	System Savings	Annual Cost Savings	Payback on Investment, Years
3M Company	Laboratory Facility	10,821,000	6 %	$823,000	1.9
Louisiana-Pacific	Strand board	2,431,800	5 %	$85,100	1.0
Nisshinbo California	Textiles	1,600,000	59 %	$100,954	1.3
Alumax	Primary aluminum production	3,350,000	12 %	$103,736	0.0
City of Long Beach	Municipal waste incineration	3,661,200	34 %	$329,508	0.8
Bethlehem Steel	Fan system on basic oxygen furnace	15,500,000	50 %	$542,600	2.1
Other Showcases	Various	1,299,734	31% (avg.)	$181,432	2.16 (avg.)
Total/Average		38,663,734 or 131 tBtu	35 %	1,984,898	1.18

For More Information

Scheihing, Paul E. (U.S. Department of Energy, Office of Industrial Technologies) et. al., "United States Industrial Motor-Driven Systems Market Assessment: Charting a Roadmap to Energy Savings for Industry," available at http://www.motor.doe.gov/docs/utrecht.shtml