## Clean Cities Partnership Program for Alternative Fuels

The DOE Clean Cities Program is a voluntary, locally based, government/industry partnership to expand the use of alternatives to gasoline and diesel fuel by accelerating the deployment of alternative fuel vehicles (AFVs) and by building a local AFV refueling infrastructure. Alcohol fuels liquefied petroleum gas, electricity, and compressed natural gas are considered to be the principal alternatives to gasoline. Over the past four years, approximately 70 communities across the country have joined the national Clean Cities effort, bringing with them approximately 139,000 AFVs in both public and private fleets, and 3,900 alternative refueling stations. These vehicles reduced gasoline and diesel fuel use by an estimated 132 million gallons and carbon emissions by an estimated 230,000 metric tons in 1998.

There are a number of significant Clean Cities success stories, including the Tulsa Public School District, which operates 190 vehicles to run on compressed natural gas and propane. El Paso, Texas, recently celebrated becoming the first city in the nation to meet DOE's 100% niche market alternative fuel vehicle challenge. The El Paso U.S. Postal Service fleet is now 100% alternatively fueled, with all its 397 delivery trucks operating on compressed natural gas. In southern California, the Long Beach Clean Cities Coalition brought together the City of Long Beach, L.A. Checker Cab Company, Southern Cali-fornia Gas Company, and Pickens Fuel Company, which resulted in the deployment of 140 natural-gas-fueled taxicabs. The benefits from this partner-ship include reducing non-methane organic gas emissions by 6,352 lb/year, carbon monoxide by 92,511 lb/year, and oxides of nitrogen by 11,101 lb/year.


The Clean Cities Program has also been a magnet for other federal funding, attracting approximately $275 million for alternative fuel projects from the Federal Highway Adminsitration. Estimated energy savings from the 139,000 AFVs in Clean Cities Program are equivalent to 0.048 quadrillion BTUs. From 1993 to 1998, cumulative savings of 380 million gallons of motor fuel. This has avoided the emission of 0.40 million metric tons of carbon into the atmosphere and has saved about $900 million in oil-based fuels over the life of the program.

DOE's Clean Cities Program has awarded $9.6 million to fund 117 projects with matching funds, which includes co-funding from private sector and local governments. Most grants are less than $100,000 and are administered by the host state's energy office. Cumulative DOE funding for the Clean Cities Program is approximately $15 million. This funding has been matched by a total of $36 million from state organizations, participating stakeholders, local alternative fuel suppliers, and others.

### References

http://www.ccities.doe.gov

## Cellulose-to-Ethanol Program

The National Biomass Ethanol Program encompasses research and development projects aimed at developing a competitively successful domestic industry based on converting cellulosic biomass to ethanol for use as a clean-burning alternative to gasoline. The program is a critical element in The U.S. strategy to decrease dependence on foreign sources of petroleum while reducing atmospheric carbon emissions. R&D activities have initially focused on improving the efficiency of the biomass-to-ethanol conversion processes.

> *This facility [in Jennings, Louisiana] is a giant step toward alternative fuels that are domestically produced and based on low-polluting energy sources. We can look forward to the day when a ton of biomass will be traded like a barrel of oil is today.*
>
> —Bill Richardson, U.S. Secretary of Energy

Waste biomass such as forestry and wood waste, sugar cane residue, rice hulls, and other organic material is significantly cheaper than traditional feed stocks such as corn and grain, but its chemical composition has prevented it from being used to make ethanol economically. Ethanol produced by conversion of waste biomass will now be economically competitive with fossil fuels for the first time because of technological breakthroughs made by the National Biomass Ethanol Program.

Ground was broken for the first commercial biomass-to-ethanol plant in October 1998 in Jennings, Louisiana. BC International Corporation will use a patented, genetically-engineered microorganism in its process of converting organic material to ethanol, a form of alcohol used as an industrial chemical and as "clean-burning" motor fuel. The new plant is expected to produce 25 million gallons of ethanol per year.

DOE has invested $11 million towards the retrofit of an existing industrial site in Jennings to accommodate the new technology for producing ethanol. The total renovation cost is estimated to be $90 million, for which the private sector is providing about 88% of the total capital investment. A cogeneration facility will also be built to produce the plant's electrical power. The facility will eventually employ 50 full-time personnel.

## Benefits and Costs

While the appropriations for the national biomass-to-ethanol program have been relatively modest (e.g., about $130 million through 1998), the benefits are expected to be quite large. For example, the use of ethanol blends in gasoline is estimated to have displaced 1.53 quads (worth $12 billion) oil-based fuels

through 1998, thereby reducing carbon emissions by 5.0 million metric tons. The ethanol produced by the Jennings plant is expected to displace almost one-half million barrels of imported oil annually.

## References

U. S. Department of Energy, Office of Fuels Development, Office of Transportation Technologies, "National Biomass Ethanol Plan," FY 1999 – 2005 (Dec. 3, 1998), Draft.

## FEMP AND REGIONAL OFFICES HELP DEPLOY EXISTING TECHNOLOGIES

The Federal Energy Management Program (FEMP) and EERE's Regional Offices (ROs) are critical links in bringing programs and technologies to federal agencies and local communities. Working with state energy and weatherization offices, and in partnership with other federal agencies, these programs and offices promote energy efficiency through a broad range of EERE activities that provide information, technical assistance, and financial help to local, state, and regional customers, as well as to other federal agencies. A sample of their accomplishments is described below.

### *The Forrestal Building Relighting Project*

DOE has achieved significant energy efficiency improvements in its own headquarters building (the James A. Forrestal Building) in Washington, D.C. In 1989, a team of energy specialists from the Federal Energy Management Program identified lighting as an area in which energy use could be reduced substantially. A monitoring program showed that the building's more than 34,000 1-foot by 4-foot fluorescent lighting fixtures were responsible for 33% of the building's total annual electric bill. Innovative financing was required to invest in improved lighting because government-appropriated capital funds were unavailable.

After issuing a request for proposals, a contract was awarded to EUA Cogenex Corporation of Lowell, Massachusetts. Work begin in March 1993. The finished project met all of DOE's goals. As a result of the new lighting system:

- Annual energy lighting consumption was reduced by approximately 6 million kWh.
- Annual savings are estimated to be about $400,000.
- Lighting power density was reduced from 2.2 to 1.0 watts per square foot.
- Lighting levels were increased from 43.4 to 58 footcandles.

According to DOE's facilities manager, the project was an unqualified success: "The total building electrical energy consumption was reduced by 18% as a result of this project, which was made possible by alternative financing. Significant energy savings were achieved while the overall lighting quality throughout the building improved."

### *The Seattle Regional Office Community Initiative*

To target resources to best meet the comprehensive needs of communities in the region, the Seattle Regional Office has been implementing a Community Initiative since January 1997. The staff identify communities interested in participating; make joint presentations (with state energy offices, EPA staff, or others) to community leaders; develop projects and broker assistance from existing resources to meet community needs; and follow up to determine results. The DOE cost has been about $25,000 to date. Here are some of the early results of these efforts:

- In Los Angeles DOE provided design assistance to the city for the $50 million redevelopment of the Pico Aliso Public Housing project. The state has agreed to incorporate several of the "green" design recommendations into Pico Aliso and subsequent public housing construction and retrofit projects. The city began development of a green housing initiative centered in its Empowerment Zone and joined DOE's Rebuild America Program.

- After a joint presentation by DOE, the California Energy Commission, and Center of Excellence for Sustainable Development to city and county staff in San Diego, the city made a commitment to expand its existing efforts with DOE and develop a broad-based city energy efficiency effort tapping the resources of EERE's Rebuild America, Clean Cities, and Motor Challenge programs.

- In March 1998, DOE, ICLEI, state officials, and EPA staff made a joint presentation to city officials in Tucson, Arizona. Numerous resource commitments were made to help the city reduce greenhouse gas emissions. The city helped form a Million Solar Roofs coalition and is likely to join Rebuild America.

***Energy Efficient Buildings in Wake of Flooding in North Dakota***

After damaging floods in Grand Forks, North Dakota, in 1997, the Denver Regional Office consulted with the University of North Dakota's Energy & Environmental Research Center (EERC) and gave seed money of $40,000 to support the center's role as local champion for energy-efficient, sustainable, rebuilding strategies. As a result, energy efficiency, previously not considered in rebuilding plans, was incorporated into many new buildings and reconstructions:

- Grand Forks County Building was rebuilt with energy-efficient insulation, lighting, windows, daylighting strategies, and control systems, which will result in estimated energy costs of $0.71 per square foot compared to the $1.50 per square foot for conventional buildings in the area.

- First Presbyterian Church rebuilt using a passive solar design, energy-efficient windows, and a geothermal heat pump. Bible Baptist Church also installed a geothermal heat pump.

- University of North Dakota became a Rebuild America Partner.

- A local citizen learned about geothermal heat pumps through EERC's outreach and donated $50,000 to install the technology in the Grand Forks Library.

- Cavalier Air Station, outside Grand Forks, responded to EERC's outreach by allocating $50,000 for a feasibility study of geothermal heat pumps for the facility.

***The Rebuilding of Valmeyer, Illinois***

After it was destroyed by flooding in 1993, the City of Valmeyer, Illinois, decided to relocate and rebuild on higher ground. The mayor asked EERE to help design the new town. EERE's Chicago RO assembled a team of national experts who held four design charrettes for the community over a four-month period, educating community members about energy efficiency, solar access, and sustainable community principles. The Illinois Energy Office contributed by offering incentive packages of $1,300 each to homeowners who volunteered to meet progressive energy-efficiency standards that far exceeded national standards. The results of this assistance were:

- 30% savings in energy use (resulting from approximately 40% heating and hot water energy savings and 20% reduction in overall electricity use);

- many homes were built to high energy efficiency standards, including 49 which received energy-efficiency grants; and

- the school system has realized a $50,000 per year savings from energy-efficient rebuilding, and the Fire Station/Civic Center has realized an energy savings of $30,000 per year.

*Hualipai Tribe Uses Photovoltaic Pumping System and Water Pipeline*

Northwestern Arizona's Hualapai tribe in Peach Springs, Arizona, has limited income sources and a 70% unemployment rate. The tribe's tourist facility on the Grand Canyon rim drew some 500 visitors per day, but lacked the necessary water supply to support their expansion potential. Lack of water also limited stock-grazing options. DOE co-funded the purchase and installation of a PV system to pump water 26 miles from a well to the facility and surrounding area.

- The Hualapai Tribe has been able to significantly improve the solar-powered Westwater water pipeline to provide much needed water for cattle and wildlife on this arid portion of the reservation.
- Through their success, the tribe has significantly improved its chances of completing the pipeline to Grand Canyon West, which will in turn open opportunities for economic development and employment for tribal members.

*Southwestern U.S. Postal Service moves to Alternative Fuel Vehicles*

In September 1998, the U.S. Postal Service (USPS) in El Paso, Texas, celebrated becoming the first city in the nation to meet DOE's 100% alternative fuel vehicle challenge. The El Paso postal fleet is the first in the nation to commit to operating all of its 397 delivery vehicles on compressed natural gas.

- The Southwest Region of the USPS now operates over 1,500 bi-fueled, compressed natural gas vehicles, of which 950 are in Dallas – Fort Worth. The vehicles are refueled at 23 public/private fueling stations throughout the metroplex.

- During 1998, five 9-ton USPS trucks operating on liquefied natural gas were put into operation in the Dallas – Fort Worth area. This is USPS's first large-scale demonstration of using liquefied natural gas to fuel heavy-duty trucks. By mid-1999, USPS plans to convert all 128 of the 9-ton trucks operating from the Dallas – Fort Worth bulk-mail center to liquefied natural gas.

- On January 13, 1999, The USPS Southwest Region dedicated its first-of-a-kind environmental postal facility in Fort Worth. This new design concept for post offices features the efficient and sustainable use of natural resources, natural landscaping and rainwater harvesting system, compressed wheat straw wall construction, energy-efficient heating, cooling and lighting systems, use of recycled materials, and use of alternative-fuel vehicles.

*Aquaculture Industry Develops in North Carolina*

The Energy Division of the North Carolina Department of Commerce is helping farmers across the state learn about a new year-round cash crop: fish. Before now the state's marine fisheries industry has been

limited almost exclusively to its coastal waters, and annual productivity was being affected by environmental impacts and fuel price instabilities.

- Utilizing nearly $400,000 in Exxon petroleum violation escrow (PVE) funds, the division, in a joint venture with North Carolina State University in Raleigh, is leading the development of warm- and cold-water aquaculture systems that can be used to raise a variety of fish species. The project is being carried out under the auspices of North Carolina's State Energy Conservation Program. Both systems are closed-loop designs utilizing energy-efficient technology created in the Scandinavian countries, which minimizes the amounts of water and energy required and allows for control of temperature, permitting year-round operation Because they are closed-loop systems they are not vulnerable to environmental impacts as are open-water fishing industries.

North Carolina's aquaculture industry has until recently been confined to the eastern and mountain areas of the state. With this technology, the only one of its kind in North Carolina, tilapia and striped bass are being grown in the warm-water system. It is estimated that a commercial warm-water system could produce 80,000 to 100,000 pounds of tilapia per year. Trout, of which North Carolina is the second largest producer in the nation, and arctic cod are being grown in cold water, and other cold-water species such as salmon and sturgeon will be introduced into this system. The marketing staff at North Carolina State are identifying sites for energy-efficient fish farms, and private capital is being sought to bring these technologies into a wider market.

# AFTERWORD – MORE SUCCESS IN THE PIPELINE

Many EERE-funded technologies have realized significant advances in the past decade but do not yet have quantified energy or cost savings. Some of these have just recently been introduced into the marketplace; others have yet to be commercialized but hold considerable promise for the future. A sample of these recent R&D successes is described here. The second half of this chapter describes an array of emerging field verification, deployment, and outreach successes. These emerging successes ensure that investments in EERE programs in the 1990s will continue to deliver benefits well into the foreseeable future.

## SUMMARY OF PROJECTED BENEFITS FROM EMERGING R&D SUCCESSES

A summary of benefits for a sample of seven EERE emerging R&D successes was calculated for this report. The seven technologies are identified in the following table, along with additional emerging R&D successes that are described in more qualitative terms later in this chapter.

**A Sample of Emerging R&D Successes**

| Buildings | Industry |
|---|---|
| ➢ High efficiency refrigerators* | ➢ Combined heat and power systems* |
| | ➢ Lost foam metal casting* |
| | ➢ Nickel aluminides* |
| **Transportaiton** | **Power** |
| ➢ Fuel cell technologies | ➢ Photovoltaic thin film partnership program* |
| ➢ High performance batteries | ➢ Biomass gasifiers* |
| | ➢ High-temperature superconducting equipment* |
| | ➢ Solar Two |
| | ➢ Photovoltaic manufacturing |

*Success metrics for these seven technologies are described below and are summarized in Appendix A.

The DOE R&D investment represented in these seven EERE accomplishments in emerging technologies collected is $288 million over a period of six years (see Table 4 in Appendix A for details). Much of this investment has been matched with cost-shared dollars and resources from industrial partners. Nickel aluminides research is an example of an emerging success that has benefited from funding from several different DOE offices, beginning in 1982. Initial research on nickel aluminides was funded by DOE's Office of Science. As the beneficial applications of this novel material became clear, both EERE and DOE's Office of Fossil Energy supported its further development. Nickel aluminides also received the earliest DOE funding of all these emerging technologies, reflecting the basic research that was first required to develop the scientific basis for this bimetallic alloy.

The potential energy saved or replaced by these seven emerging technologies is 945 trillion Btu. More than half of this (500 trillion Btu) is projected to be saved in 2010 by high temperature superconductivity equipment. An additional 290 trillion Btu will be saved if the efficiency of all refrigerators is improved to the 1 kilowatt hour per day consumption of EERE-developed high-efficiency refrigerators. Widespread use of nickel aluminides could save industry 60 trillion Btu per year while lost foam metal casting, already in use in aluminum and iron casting, will save 37 trillion Btu when it has gained sufficient market share to reduce energy requirements for melting by 30 percent.

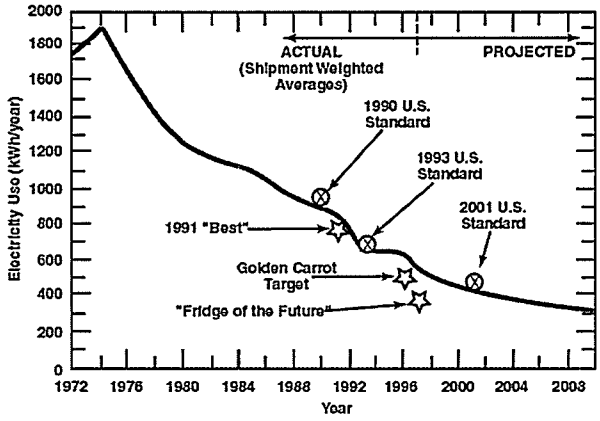
Energy cost savings from the adoption of these seven emerging technologies could save billions of dollars in the future. For example, $6 billion could be saved annually if all refrigerators used just 1 kilowatt of energy per day, as demonstrated by DOE. The application of high temperature superconductivity to reduce losses from the transmission and distribution of electricity could save $564 million by 2010. The use of nickel aluminides will save industry $180 million, and another $160 million in cost savings will come from the installation of combined heat and power systems. Estimated reduction in carbon emissions from the adoption of these emerging technologies is nearly 50 million metric tons.

Many other benefits will result from these emerging DOE technologies. Among these is a reduction in solid waste of 700,000 tons per year from the adoption of the lost foam metals casting process and millions of dollars in exports of photovoltaic thin film systems.

## A SAMPLE OF EMERGING R&D SUCCESSES

### *Setting a Technology Benchmark for Refrigerator Efficiency*

DOE's Oak Ridge National Laboratory (ORNL), in cooperation with seven industry partners, has designed a refrigerator-freezer that uses half as much energy as current refrigerators and one fifth the energy used by 1972 models. The research team modified a conventional refrigerator using highly efficient technology to reduce energy usage by 50%, from 2 kilowatt hours (kWh) per day to 1 kWh per day. One kWh is as much as a 40-W light bulb uses in a single day. The efficiency demonstrated by ORNL's "fridge of the future" helped define a benchmark for future refrigerator efficiency.




ORNL researchers assembled the prototype by modifying a standard 1996 production model refrigerator using the most promising energy-saving components and features available within companies in the Appliance Research Consortium (ARC), a subsidiary of the Association of Home Appliance Manufacturers. Baseline energy consumption of the original 1996 refrigerator was extensively documented, along with cabinet heat load and compressor calorimeter test results, to provide a firm basis for comparing the energy savings measured in the prototype high-efficiency refrigerator. The results demonstrated the degree of energy efficiency that refrigerator manufacturers could attain using existing technology and a systems engineering approach, and quantifed the costs and the paybacks. All refrigerator manufacturers will likely use one or more of the energy-saving strategies from the "fridge of the future" to meet future energy-efficiency requirements.

The huge improvement in energy efficiency in refrigerators during the final quarter of the 20th century was facilitated by DOE's long-term R&D commitment and its collaboration with the appliance industry. This work has resulted in significant savings and has laid the groundwork for realizing equally significant savings in the future.

A DOE investment of $1.1 million in R&D of high-efficiency compressors saved consumers about $6 billion in energy costs between 1980 and 1990. These compressors were developed through cooperative research agreements between a leading compressor manufacturer and ORNL and were 44% more efficient than the compressors they replaced. DOE's $1.2 million spent on refrigerator efficiency between 1991 and 1997 could save consumers another $6 billion per year and could displace 290 tBtu of energy and 12 MMTC of carbon emissions annually.

If the energy used per refrigerator dropped to 1 kWh per day—the efficiency achieved by the prototype "fridge of the future"—energy use by refrigerators would drop from 2.1% to 0.8% of the total energy used in the United States, saving another $6 billion per year. A prototype built with a fewer if these efficient technologies would save slightly less energy but achieve a payback period of less than three years because its manufacturing cost would be only $18 more than the baseline model.

***Combined Heat and Power (CHP) Systems***

Combined heat and power (CHP) systems are designed to concurrently generate thermal energy and electrical/mechanical energy, capturing waste heat and using it to heat and cool buildings or to provide steam for use in industrial processes. DOE is an active supporter of research, development, and deployment of CHP systems, with involvement dating back to the 1980s. CHP plants use of waste heat results in total system efficiencies of 70 to 90 percent — a considerable performance gain over the 33 percent average efficiency of conventional central electricity generating plants.

Combined heat and power systems, many of which combust natural gas to achieve their significant environmental benefits, universally demonstrate considerable energy and cost savings. Some of these successes include:

- In the late 1970's, DOE and the Minnesota Energy Agency, with partners Building Owners and Manufacturers Association and the U.S. Department of Housing and Urban Development, began a partnership in the city of St. Paul, Minnesota to study the feasibility of modern district heating systems. The resulting community-based organization, District Energy St. Paul, has grown and proven itself a valuable real-world CHP demonstration project. The system has been continually retrofitted over the past two decades with the best available technologies, doubling system efficiency while adding services such as district cooling.

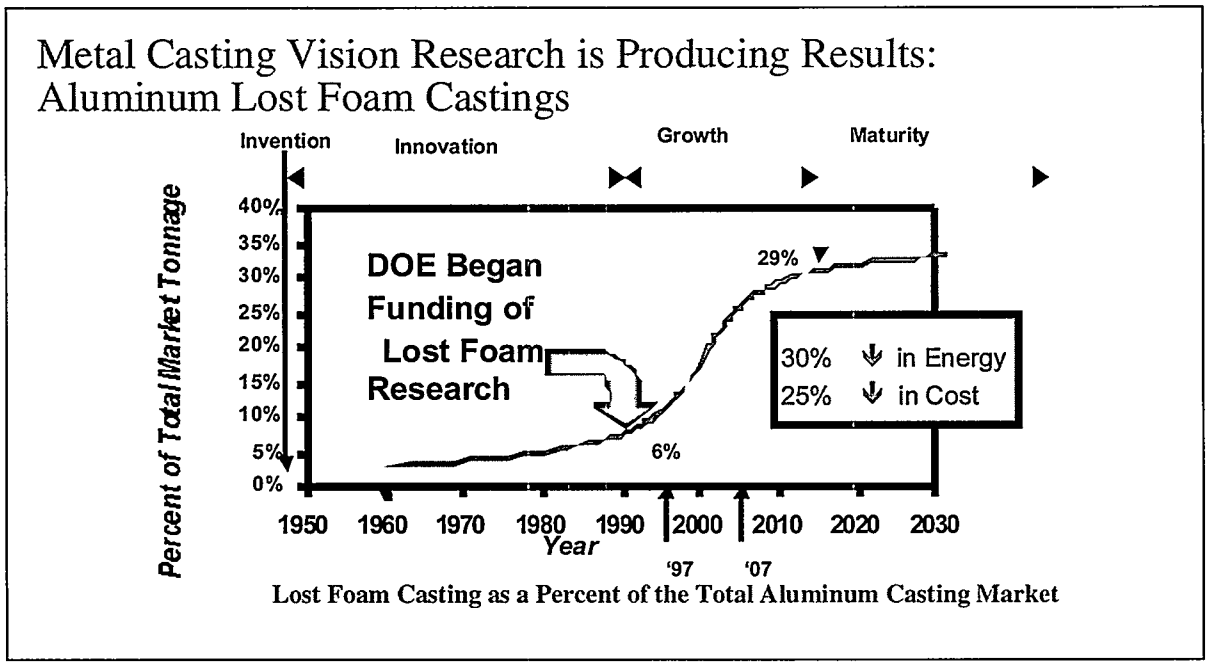
- The Department of Energy-installed cogeneration plant at the Naval Petroleum Reserve No. 1 in California supplies all electricity and steam requirements for the field. 45 percent more efficient than the private sector plant from which the Reserve once purchased power, the facility generates annual revenue in excess of $3 million. The CHP plant provides 160,000 pounds of steam per hour, allowing the Reserve to shut down less efficient gas heaters and steam boilers.

- Malden Mills, in Lawrence, Massachusetts, installed a cogeneration system to replace generating and heating equipment destroyed in a fire. Following the recommendation of OIT's Advanced Turbine Systems program, they installed a natural gas turbine-based cogen system. In one year, Malden will retrofit the turbines with ceramic liners developed within the ATS program. Once installed, this

natural gas turbine-based system will lower the company's annual energy costs and reduce emissions of $SO_2$ by 99.6 percent, $NO_x$, by 83 percent and $CO_2$ by 26 percent relative to grid-supplied power.

***Lost-Foam Metal Casting Improves Quality, Reduces Energy Consumption***

The DOE Office of Industrial Technologies, working with the Lost Foam Casting Consortium, has aggressively pursued development and demonstration of an advanced casting technology termed "lost foam." Lost foam casting is a highly flexible casting process that allows complex metal components to be cast into final or near-final form, reducing waste and additional energy expenditures incurred by the extensive milling process required in conventional casting. An estimated 40,000 tons of lost foam aluminum castings were produced in 1994, rising to 50,000 tons in 1997. Growth through the year 2000 is expected to increase by 64 percent, to 82,000 tons. Lost foam casting of iron is also growing, with production increasing from 20,000 tons in 1994 to 40,000 tons in 1997, to an estimated 85,000 tons in the year 2000.




This DOE/private partnership, begun in 1990, is part of DOE's Metal Casting Program. DOE funded $1,557,742 worth of lost foam research over the period FY1992 to FY1997, largely at the University of Alabama Birmingham. Industry cost-share during the same period totaled $1,975,391. Work has been completed in several areas of the casting process, including patterns, coatings, sand reaction, and properties of the castings.

The benefits to be realized from the precision lost foam casting process include:

- The lost foam process requires less metal to be melted than other processes. An estimated 30 percent reduction in energy requirements for melting could save about 37 trillion Btu per year, or $78.44 million.

- The process led to a 17 percent reduction in distortion scrap by one partner foundry, and a scrap reduction rate drop of 5.5 percent to 0.25 percent in another partner foundry. Overall potential is a reduction of 700,000 tons/year of solid waste by the year 2000.
- Lost foam tooling life is at least 5 to 6 times that of permanent mold or die cast tooling, saving capital expenditures.

*Nickel Aluminide R&D Increases Operational Efficiency*

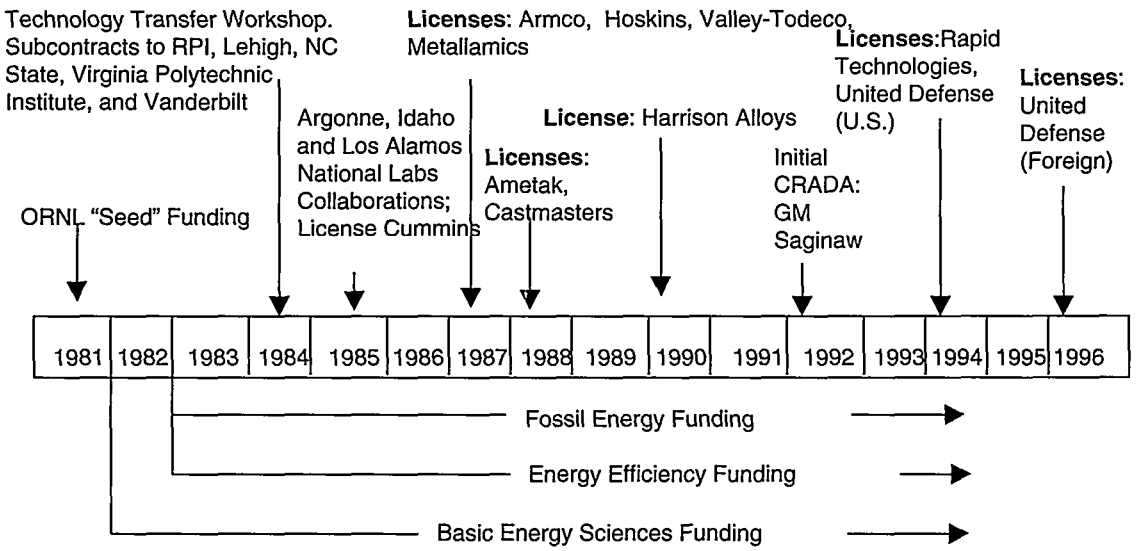
Nickel aluminides ($Ni_3Al$) are unique intermetallic materials that combine extraordinary strength and hardness with very high melting points. These materials are potentially useful in such strategic industrial sectors as steel, chemicals, and automobile manufacturing. The harsh conditions under which nickel aluminides display their unique set of properties points to their promising use as rolls and fixtures in steel mill furnaces, as dies for precision parts or as "dies for dies," and in various other high-temperature and extremely corrosive operating environments.

Since 1982 DOE's Offices of Basic Energy Sciences, Fossil Energy, and Energy Efficiency and Renewable Energy together have provided more than $21 million toward the successful development of strong, castable, weldable, and ductile nickel aluminides and other intermetallic alloys, and to develop the Exo-Melt production process. In addition, industrial partners have spent over $12 million on DOE-related $Ni_3Al$ materials, applications development, and testing. Industry contributions occur through Cooperative Research and Development Agreements (CRADAs), collaborative materials and process evaluations, and licensing. The work of DOE and its partners has resulted in increased industrial acceptance of these materials and processes, as shown by a growing network of suppliers and users that spurred commercial sales of $Ni_3Al$ to $3,000,000 at the close of 1998. The total energy savings in heat treatment of steel are estimated at 60 trillion Btu by 2015 at an energy cost savings of $180 million per year.

Experiences of industrial partners includes:

- Delphi is using $Ni_3Al$ heat treating trays in their parts furnaces; results indicate that $Ni_3Al$ fixtures last more than four times longer than conventional HU trays. Longer tray-replacement periods could result in savings of $2 million annually.
- Chevron is testing and utilizing $Ni_3Al$ tube hangers in chemical reaction systems to alleviate problems with high-temperature corrosion.
- United Defense is realizing reduced total die costs, improved production rates, and increased recycling values using $Ni_3Al$ forging dies instead of steel dies.
- Bethlehem Steel has installed 21 rolls in a steel slab reheat furnace to decrease furnace downtime while improving product quality, thus saving time and energy, and improving competitiveness.

**Documented Progress on a Time Line Helps Demonstrate Causality**




The nickel aluminide program's history of industrial licensing, partnership, and CRADAs shown here is one indicator of the $Ni_3Al$ program's value as viewed by the private sector. The period over which licenses have been granted suggests a continuing line of scientific advancement, and offers a preview of the uses and savings that industry may realize.

***Photovoltaic Thin Film Partnership Program***

Photovoltaics (PV) is an energy technology that makes use of semiconductor materials to convert sunlight directly to electricity. It is basically divided into "wafer" and "thin-film" technologies. Wafer-like solar cells cut from ingots of crystalline silicon have been available commercially for decades. The idea of thin films is relatively simple: produce low-cost PV devices by using materials that are amenable to integrated module manufacturing methods instead of the labor-intensive mechanical configuration of individual cells required by wafer-based PV technology.

Through twenty years of R&D, DOE has helped pioneer thin-film technology by developing new semiconductor materials such as amorphous silicon, copper indium diselenide, and cadmium telluride (CdTe), which should be less costly to produce in the large panels or "modules" needed for utility-grid-connected applications. In FY1994 DOE established the Thin Film Partnership Program to focus the development of new materials and to help solve industrial problems by funding cost-shared contracts with several thin-film manufacturing companies. The partnership stimulates collaboration among the national laboratories, universities, the PV industry, and ancillary industries. The long-term (2010 and beyond) goal of the partnership is to develop modules that produce 150 watts of power per square meter at a module price of $50 per square meter. Reaching this goal will ensure achievement of the long-term DOE goal of a PV system that produces electricity at 6 cents per kilowatt-hour. By the year 2020, thin film technology is projected to displace 17 trillion Btu annually, saving $54 million in fuel costs and reducing carbon emissions by 0.25 million metric tons.

DOE's budget for thin films has averaged $17 million per year from 1994 to 1999. Benefits include advances in thin-film technologies and commitments for the construction of the first four multi-megawatt thin-film production facilities. In January 1999 DOE established a new world record for all thin-film cells with a copper indium gallium diselenide (CIGS) solar cell efficiency of 18.8%, breaking its previous record of 17.7% set in March 1996 (see graph on the next page). DOE's thin-film R&D efforts have also been awarded several noteworthy prizes: four R&D 100 awards, a Discover Award from Discover Magazine, two Federal Laboratory Consortium "Excellence in Technology Transfer" awards, and a Popular Science "Best of What's New" award have been received for thin-film materials development.

This 10-kilowatt PV array using CdTe thin-film technology feeds electricity into the Toledo Edison utility grid. Solar Cells, Inc. NREL/PIX01560.

***Biomass Gasifiers: Kindling Biopower Potential***

The world's first demonstration of an efficient, low-pressure biomass gasifier capable of producing a high-quality fuel gas is now operating at the Burlington Electric Department's McNeil wood-fired generating station in Burlington, Vermont. The gasifier, developed by Battelle Columbus Laboratories (BCL) and licensed by Future Energy Resources Co. (FERCO) of Atlanta, Georgia, converts 200 tons of wood chips per day into a gaseous fuel, enough to generate 8 MW of power.

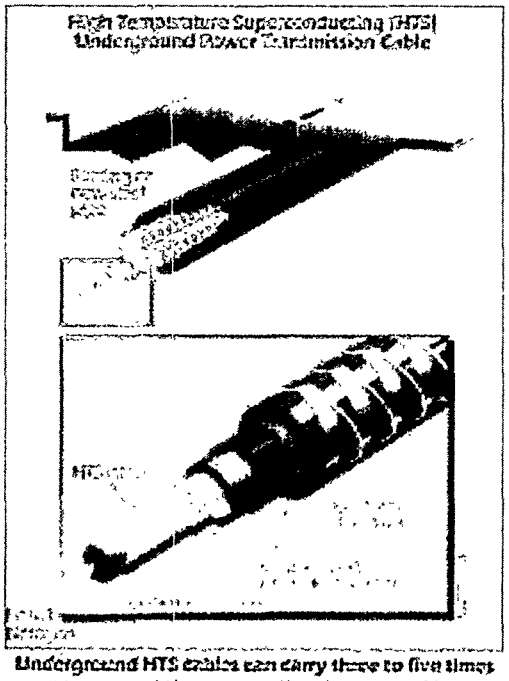
The Vermont gasifier project is part of a major DOE initiative to demonstrate gasification of renewable biomass for electricity production. DOE has provided financial and technical support for the development of the BCL gasifier technology since 1980 in a variety of ways: by supporting the initial laboratory and pilot-scale gasifier tests at Battelle, by providing engineering, scientific and analysis assistance through DOE's National Renewable Energy Laboratory (NREL), and by cost-sharing the scale-up verification tests in Vermont.

The gasifier will significantly improve biomass-to-electricity generating efficiency in applications ranging from stand-alone power generation to the forest products industry. This gasifier will allow biomass to be used with standard gas turbines and combined cycles to produce advanced power systems with efficiencies that can exceed 35% —nearly double that of today's biopower industry. That means twice as much electricity for each pound of biomass converted, or half as much fuel required for each kilowatt of electricity generated. Because of its economic potential and scientific accomplishment, the gasifier team, including FERCO, Battelle, Burlington Electric Department and NREL, was given an R&D 100 Award for one of the most significant technical achievements in 1998.

A recent analysis by a consortium of five national laboratories (and consistent with industry estimates) indicates that, if fully adopted, this technology could generate 40,000 GWh of electricity in the forest products industry alone while avoiding 14 million tons of carbon emissions per year. By the year 2010, biomass gasifiers are projected to displace 14 trillion Btu of energy, saving $2 million in energy costs and reducing carbon emissions by 0.24 million metric tons.

*High-Temperature Superconductivity*

Superconductivity will bring the most fundamental change to electric power technology since electricity use in the United States became widespread a century ago. Superconductivity is the ability of certain materials to conduct electrical current with no resistance and extremely low losses. Recently discovered high temperature superconductors (HTS) are exciting because they can be cooled more economically and efficiently than low-temperature superconductors. This ability to carry large amounts of current can be applied to electricity transmission in power lines and electric power devices such as motors and generators. In much the same way that fiber optic cables created the "information superhighway," superconductivity will create an "energy superhighway" that greatly increases capacity and energy efficiency. Superconducting technology will also help open the deregulated electricity market to smaller electricity producers by making transmission of electricity more economical.



Underground HTS cables can carry three to five times more current than conventional copper cables.

DOE has championed research for the development of super-efficient electrical systems and has played a critical role in mobilizing the private sector, universities, and the national laboratories to conduct research and development and bring HTS technologies to the marketplace. The combined efforts of DOE, companies such as American Superconductor Company, and the national laboratories are now beginning to pay off. In 1999, researchers at DOE's Oak Ridge National Laboratory (ORNL) and a team led by Waukesha Electric have built and tested a 1-million-volt-ampere prototype power transformer. Superconducting transformers are half the size and weight of conventional transformers, and have only half the energy losses.

The world's first urban superconducting power line will become a reality in the year 2000 as part of the DOE program. The equivalent of 30,000 households will be served in a downtown Detroit neighborhood slated for several major redevelopment projects. Team members in addition to Detroit Edison are American Superconductor Co., the Electric Power Research Institute, and Los Alamos National Laboratory.

A recent study funded by DOE suggests that half the 7.35% of electricity that is lost in transmission and distribution could be saved. The resulting 3.67% savings (currently equivalent to about 500 trillion Btu), if used to reduce coal-fired electricity generation, would eliminate the emissions of 131 millions tons of $CO_2$, 24,232 tons of $NO_x$, and 846,000 tons of $SO_x$ , based on 1995 coal plant technology. The projected annual energy benefits in 2010 of HTS for all equipment types is $564 million.

*High-Efficiency, Low-Emissions Fuel Cell Technologies for Transportation*

The United States can benefit greatly from the commercialization of fuel cell technology. Transportation accounts for 67% of the petroleum consumption and one-third a balance of trade surplus in the transportation sector. Vehicles powered by fuel cells offer important advantages over conventionally powered vehicles. A fuel processing system could deliver about 85% of the energy in a gallon of gasoline

to the fuel cell, and the fuel cell could turn more than half of that energy into electricity for a total system efficiency of over 40%. In contrast, an internal combustion engine uses less than 20% of the energy in a gallon because of losses including cycle inefficiency and friction. It is estimated that a fuel cell system running on gasoline would achieve double the miles per gallon of a conventional vehicle or 50 to 70 miles per gallon. Fuel cells also promise to be very low in emissions.

DOE recently concluded a cost-shared program with General Motors Corporation to develop a methanol-powered Proton Exchange Membrane (PEM) fuel cell system. At the heart of the system is an on-board fuel processor that converts methanol to hydrogen. After demonstration in the laboratory, General Motors incorporated the technology into its Zafira concept minivan and first displayed the vehicle at the Paris Autoshow in September 1998. Along with partners Arthur D. Little and Los Alamos National Laboratory, DOE has also demonstrated the potential of fuel-flexible fuel processing. The partners demonstrated the conversion of gasoline to electricity with a PEM fuel cell system, which is now the focus of all significant research on fuel cells for light duty vehicles.

The fuel cell development initiative has made impressive strides during the last decade and many of the technical goals, including those set by the Partnership for a New Generation of Vehicles (PNGV), have been achieved. Today the most significant fuel cell developments are being carried out by auto manufacturers and supply companies, including Allied Signal, Ford, Daimler Chrysler, International Fuel Cells, Plug Power, 3M, and General Motors. If fuel cell vehicles comprised 4% of all light vehicles in use in 2020, they would reduce gasoline use by 1.8 billion gallons and reduce carbon emissions by 4.7 million metric tons.

Although impressive progress has been made, and development activity both public and private has increased, foreign competition is strong and much work remains before fuel cells can compete with current vehicle technology. Key technical challenges that remain include size and weight reduction, manufacturing cost reduction, rapid start and transient performance, durability and reliability, and fuel processing. The DOE role is to encourage R&D to overcome these most critical technical barriers to commercialization.

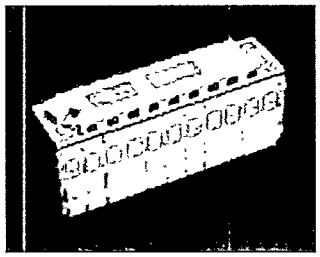
***Enhancing the Performance Characteristics of Batteries***

The energy savings and emission reduction benefits of electric vehicles (EVs) are substantial, but the lack of a battery capable of providing sufficient range and performance has long been an obstacle to the deployment of these vehicles. Today's lead-acid batteries have a limited range, allowing drivers to travel only relatively short distances before they must recharge. Current technology provides lead-acid batteries with an energy-to-weight ratio of 30-40 watt hours per kilogram (Wh/kg) at a cost of up to $150 per kilowatt-hour (kWh). The development of batteries that can provide performance comparable to that of conventional vehicles and at comparable cost is key to making electric vehicles practical.

The level of research and development required to adequately develop promising battery technologies is beyond the resources of any one automobile company. To share costs Chrysler, Ford, General Motors, and DOE entered into an agreement in 1991 to develop more efficient batteries for electric vehicles. This partnership is called the United States Advanced Battery Consortium (USABC). DOE's Office of Transportation Technologies manages the cooperative agreement with the consortium and provides technical assistance and funding.

About $190 million, cost shared equally between the government and industry, was spent from 1991 to 1996 on battery research. In 1996, a second-phase cooperative agreement worth $106 million was signed to continue work through the year 2000. The nickel–metal-hydride (NiMH) battery is the technology that has come closest to meeting midterm USABC goals, while lithium-polymer batteries are the most

promising for meeting longer-term objectives. Weight for weight, and volume for volume, NiMH batteries can store about twice the energy of the lead-acid battery. The total investment in developing the NiMH battery has been about $50 million from 1991 through 1997, including DOE's contribution of about $25 million. DOE invested $15 million per year in FY 97 and FY 98, with $7 million estimated for FY 99 costs and $8 million for FY 00.



Nickel–metal-hydride battery

Public and private investments in the NiMH battery technology have yielded concrete results. In 1996 a joint venture of General Motors and Ovonic Battery Company—GM Ovonic—began producing its first generation of NiMH EV batteries, which are used in the 1999 model year General Motors EV-1 and the S-10 Chevrolet electric pick-up truck. Daimler Chrysler has also developed a NiMH-powered interurban commuter, the EPIC, which is expected to have a range of 80 to 90 miles. Its NiMH battery is about 150 pounds lighter than an equivalent lead-acid battery. Significant cost and manufacturing challenges remain before electric batteries will be able to realize their full potential. To reduce costs further, the USABC is concentrating on three key areas: raw materials, battery design, and volume manufacturing.

***Solar Two: Clean Power on Demand***

Solar Two utilized a field of mirrors to reflect solar energy towards a centrally located tower. A unique molten salt storage system was used that allowed Solar Two to dispatch electricity after sunset and during periods of cloudy weather. Since completing its start-up phase in late 1997, the 10-MW Solar Two pilot plant has proved the potential of molten salt solar power tower technology to deliver large quantities of electric power to the grid reliably, efficiently, and on demand. These successes are critical to gaining investor confidence in large solar power plants.

DOE has provided funding for half of Solar Two's $60 million cost, with the remainder provided by a consortium of ten U.S. utilities and industries, performed on-site testing and evaluation of advanced components (e.g., the receiver and heliostats), suggested ways to improve plant performance, and chaired the Solar Two Steering Committee.

Some key recent accomplishments by Solar Two include the following:

- Dispatchability: Utilizing its unique and highly efficient thermal storage system, Solar Two delivered electricity to the grid around the clock for 153 straight hours (nearly a full week).

- Power Output: Solar Two produced 1633 MWh over a 30-day period, exceeding its long-term performance measure of 1500 MWh of power production; the plant also produced a record turbine power output of 11.6 MW.

- Reliability: During one stretch in the summer of 1998, the plant operated for 32 of 39 days (4 days down because of weather, 1 day because of loss of offsite power, and only 2 days for maintenance.

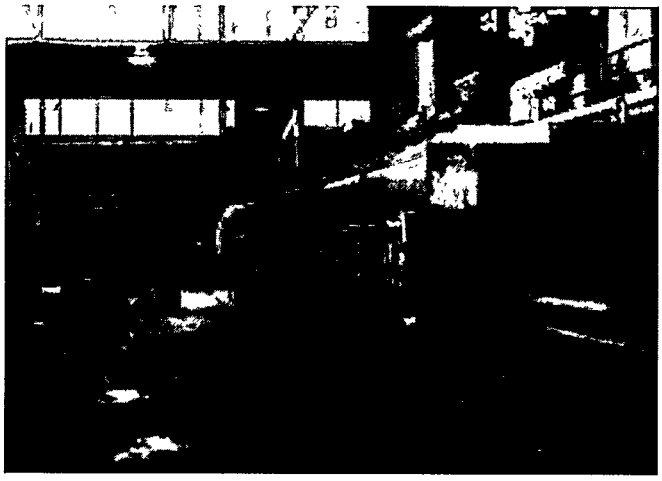
- Parasitic Power Use: The electrical parasitic energy load (electricity required to run the plant) was reduced significantly and now routinely meets the design goal.

- Efficiency: The receiver efficiency was measured at 88%, as per design specifications.

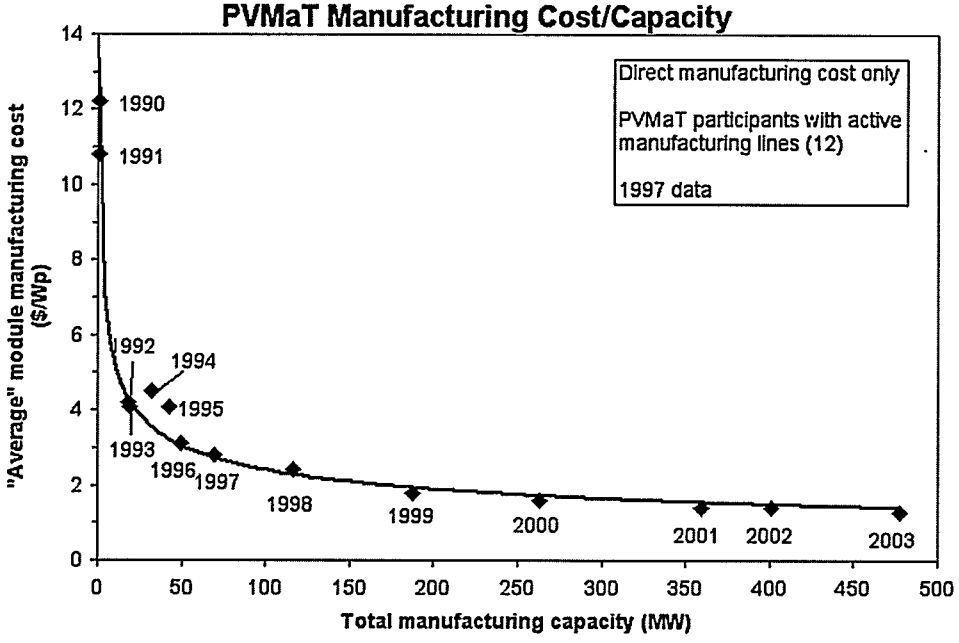
With Solar Two ceasing operations in April 1999, long-term reliability remains an issue that can only be fully resolved by operating a plant reliably over an extended period of time—and results to date suggest that this is an achievable goal.

### *Photovoltaic Manufacturing Improvements*

Photovoltaic manufacturing costs and capacity will continue to improve over the next few years with the help of the Photovoltaic Manufacturing Technology (PVMaT) Project. Initiated in 1990 to reduce costs and maintain the U.S. PV industry's leadership in developing and manufacturing commercial PV modules and systems, PVMaT is one of the most successful DOE-sponsored R&D projects in the history of the Photovoltaics Program, helping to reduce module manufacturing costs by 37% and increase U.S. manufacturing capacity by 276% from 1992 to 1997. Additional advances are expected to reduce PV module costs to the point where PV systems are competitive with small diesel systems and grid extensions in many developing countries and in other niche grid-connected applications. These applications represent several billion dollars' worth of business.



**Glass Coating Furnace at Solar Cells, Inc.**
NREL/PIX 04572



DOE provided $72 million in project funds for PVMaT from 1990 to 1998, with an additional $50 million provided by private industry (41% of total project costs). The public has already recouped its portion of the funds spent on this research through a direct reduction in the price of PV products, and has also benefited from the creation of 150 to 1500 jobs, an improved trade deficit (70% of these products are sold outside the United States, with $128 million worth of modules and cells exported in 1997), and reduced greenhouse gas emissions. This benefit will grow as photovoltaics increase their market penetration within the United States and throughout the world.

## A SAMPLE OF EMERGING FIELD VERIFICATION, DEPLOYMENT, AND OUTREACH SUCCESSES

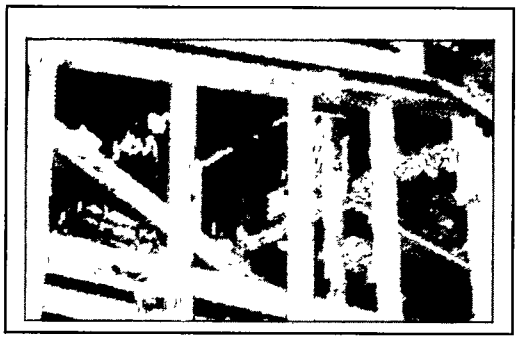
This section describes 10 field verification, deployment, and outreach successes that have accelerated and expanded the use of efficient and renewable energy technologies. In addition to the nine successes listed by sector in the following table, one cross-cutting accomplishment is described: the Million Solar Roofs Program.

**A Sample of Emerging Field Verification, Deployment, and Outreach Successes**

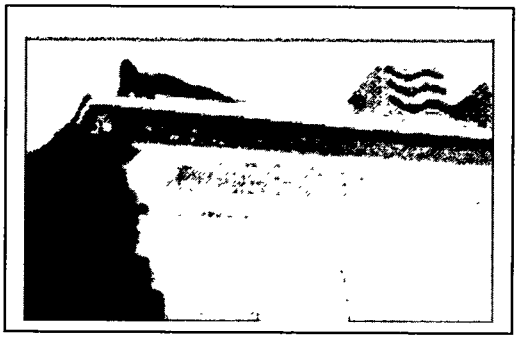
| Buildings | Federal |
|---|---|
| ➢ Building America | ➢ FEMP on Target to Meet Goals |
| ➢ Greening Four Times Square | ➢ Renewable Energy Technologies in Federal Facilities |
| | ➢ FEMP Lamp Swap |
| | ➢ FEMP Helps Government Buy Energy Efficient Products |
| **Transportation** | **Power** |
| ➢ Federal Fleet Alternative Fuel Acquisition | ➢ Climate Challenge |
| ➢ High Temperature Materials Laboratory | |

## Building America: Innovation Through Systems Engineering

The Building America Program brings together teams of architects, builders, contractors, and equipment manufacturers to apply a systems engineering or "whole building" approach to single-family home design and construction. With 100 industry partners, this approach has led to dramatic improvements in energy efficiency at little or no net increase in construction cost.



*The air handler in this Building America house is installed within the conditioned space.*



*The stucco soffit connects directly to the plywood roof sheathing completing the house's air flow retarder.*

## The DOE Role

In 1991, DOE began providing funding to Integrated Building and Construction Solutions (IBACOS), a Pittsburgh-based design firm, for their development of a systems engineering approach to new home construction. Working in concert with builders, contractors, and materials and equipment suppliers, IBACOS designed pilot homes for communities in Pennsylvania, Texas, and California. These initial prototypes realized 30 to 45 percent energy savings over the builders' standard performance at construction costs from $20 less to $20 more per house. Based on the success and promise of these early efforts, DOE launched the Building America Program in 1993 to encourage the development of additional public–private partnerships to pursue systems engineering concepts in production-scale building throughout the United States.

Through a competitive process, three consortia (Building Science Consortium, the Hickory Consortium, and the Consortium for Advanced Residential Buildings) joined IBACOS to create the program's four Building America teams. Consortia members work together to design, build, and test prototype homes. DOE provides cost-sharing funds to the consortia for staffing and project design, builder/contractor training, and monitoring activities. The National Renewable Energy Laboratory (NREL) provides field support to the consortia, including project evaluation, independent testing, and outreach to the building industry. No DOE funds are used for construction costs, building materials, or equipment.

## Benefits and Costs

DOE invested $13.6 million in R&D and technical assistance through the Building America Program from 1995 through 1998. Current funding for the program is $5 million per year. Cost sharing on the part of each team has greatly exceeded the minimum goal of 50% for the program. The membership of each

team continues to grow as additional building, finance, and appliance partners become involved. The four teams currently include 80 companies.

Building America designs and technologies are being adopted by builders and incorporated into a growing number of new homes around the country. Building America's members construct over 30,000 homes in the United States each year. In addition, subcontractors working on Building America projects are taking the new techniques and expertise to other projects. Building codes are being reevaluated and updated to accept innovations introduced by the Building America teams, and new products are being commercialized as a result of the Building America program. Some of the specific accomplishments of each team are described below.

**Building Science Consortium.** This team is working in 12 states to design cost-effective, energy-efficient single-family homes for each of four U.S. climate types. Builder members have adopted Building America concepts for the construction of approximately 2500 homes in 17 communities, more than 250 of which have been completed. Re-engineering and design is underway in 8 other locations. Results from a year-long testing program at Prairie Crossing in Grayslake, Illinois, confirm that their techniques allow for 50 to 60 percent energy savings over the regional standard construction practice at a small incremental cost over that builder's standard practice.

**Consortium for Advanced Residential Buildings.** The CARB team begins each project by creating a completely new design for each prototype based on an existing plan of the builder partner. This initial stage formulates architectural solutions that lend themselves to efficient mechanical and structural systems. Using this integrated approach, the CARB team has completed four prototypes that have used significantly fewer resources to build, while still achieving energy savings of 20% to 35% over their accompanying control houses. If built on a production scale, which is planned for at least one prototype, construction cost savings can be achieved.

**Hickory Consortium.** This team is working with multi-family housing including factory-built modular housing. In 1998, it completed work on the Cambridge Cohousing development in Cambridge, Massachusetts. This 41-unit planned neighborhood is demonstrating energy savings of 50 percent over the Massachusetts Energy Code (prior to adoption of the 1995 Model Energy Code). Hickory has also completed the engineering and specifications for a 61-unit high rise apartment complex in Boston and two prototype duplex homes. Plans are underway to integrate energy desing features in an additional 60-unit multi-family complex in Boston.

**IBACOS.** Since joining efforts with DOE in 1991, IBACOS has conducted successful design and construction partnerships in 10 states to deliver single-family homes of higher efficiency, quality and affordability. IBACOS partners with innovative builders and developers in a commitment to continually challenge and improve building practices. To date, working relations with 18 builders and developers have resulted in the construction of 268 homes built to the higher standards of Building America. In addition, six Pilot Homes have been built and tested to expand field and technical understanding of advanced building system technologies into the mainstream marketplace. Past performance achievements include 30 to 60% utility savings to the homeowner annually with no additional cost to the builder.

**For More Information**

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

Farrar, S., Hancock, E. and Anderson. R. 1998. "Systems Interactions and Energy Savings in a Hot Dry Climate" *Proceedings of the ACEEE 1998 Summer Study on Energy Efficiency in Buildings*, 1:79-92.

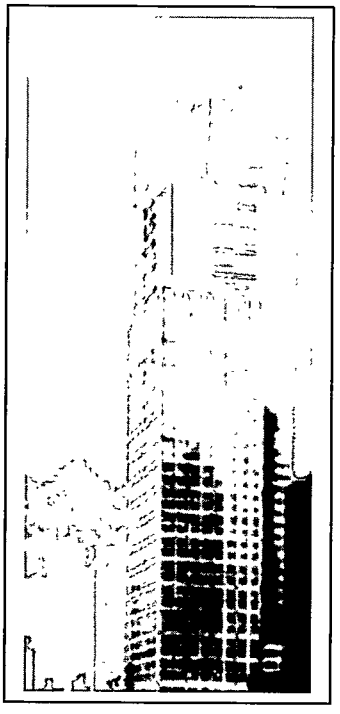
## Greening Four Times Square

Four Times Square—a 48-story skyscraper and the first major construction project in Manhattan in ten years—is one of the most environmentally and technologically advanced buildings in the nation, and is being called the first environmental office building in New York. The Four Times Square project is one of more than 8,500 projects that have been supported by grants from DOE's State Energy Program.

The Durst Organization set out to build an environmentally responsible or "green" 1.6 million square foot speculative office building which would be the first project of its size to adopt standards for energy efficiency, indoor ecology, sustainable materials, and responsible construction, operations, and maintenance procedures. The developers are confident that their next building project will surpass even the benchmarks set by Four Times Square.

## The DOE Role

The developer's determination to build "green" drew the interest and assistance of many energy experts. DOE's role was carried out through the New York State Energy Research & Development Authority (NYSERDA), one of many U.S. state energy offices that act as catalysts for public–private partnerships to encourage deployment of energy-efficient technologies. A NYSERDA grant, funded by DOE's State Energy Program, supported the developer's use of the advanced energy analysis program – DOE-2. The program's analyses were used as a primary basis for the selection of all HVAC and lighting systems and exterior cladding materials and techniques.



Building designers aimed to maximize daylight; install energy-efficient, low-emission, CFC-free chillers for the HVAC system; use fuel cells and photovoltaic cells to generate 3500 megawatt hours of electricity on site per year; and provide superior indoor air quality in the office spaces. Their biggest constraints were economic factors and the contractual requirement to allow tenants to determine how their interior spaces would be designed. The architects found that the hard economic analyses from DOE-2 runs were critical in gaining tenants' favor for energy-efficiency measures by showing their financial benefits.

## Costs and Benefits

**The Four Time Square Project.**

The energy-efficient technologies employed in the skyscraper are expected to reduce operational costs by 10 to 15% relative to a comparable project. Overall payback for the incremental costs in making the skyscraper energy efficient is expected to be between 6 and 10 years. The economics of some of the individual technologies are discussed below.

- The high transmittance glass selected for the skyscraper's windows, which take up 7 feet of a 9-foot ceiling height, could effectively provide daylight to 25% of a given floor. Payback for the glass is approximately 14 months.

- Natural gas-fired CFC-free absorption chillers are extremely efficient with a payback of approximately three years. They avoid the substantial energy waste normally lost in transmission from electric power plants to buildings.

- The two on-site fuel cells generate about 3,500 megawatt hours per year. Fuel cells are large natural gas conversion systems that generate extremely clean power via a chemical reaction. No combustion is involved and the byproducts are hot water and $CO_2$. Depending upon the price of natural gas, payback could be less than 10 years.

- Photovoltaic (PV) cells are being used to a limited degree to generate energy as an on-site demonstration. The PVs are integrated into the "spandels" on the building—the area of the façade between the top of one window and the bottom of another. A "thin-film" type of photovoltaic was selected because the paybacks were far better than with the crystalline type. The PV cells were laminated onto tempered glass and structurally glazed with the façade. The peak output of the installation is about 15 kW, approximately equaling the electricity needs of five or six suburban homes.

**The State Energy Program.**

Since 1996, NYSERDA has used $305,000 of funding from DOE's State Energy Program to provide assistance for projects valued at over $1 billion. Studies show that if NYSERDA recommendations are implemented the energy efficiency of these buildings will exceed the requirements of the New York State Energy Code by an average of 34% with an increase of less than 1% in construction cost and a simple payback of 3.5 years.

State energy offices nationwide have leveraged $4 in non-federal funding for each dollar of funding from DOE's State Energy Program, generating dramatic improvements in energy efficiency as well as economic and environmental benefits since the program's inception in 1976. DOE's State Energy Program has helped over 69,000 school and hospital buildings become more energy efficient, saving hundreds of millions of dollars in annual heating costs and enabling these institutions to make better use of taxpayer dollars.

**For More Information**

*Lessons Learned Four Times Square: An Environmental Information and Resource Guide for the Commercial and Real Estate Industry.* Author: Pamela Lippe, et al. Date: 5/97. Publisher: Earth Day New York, 205 East 42nd Street, Suite 1314, NY, NY 10017. Phone: 212-922-0048, Fax: 212-922-1936.

http://home.dti.net/earthday/Building.html

## Federal Energy Management Program On Target to Meet Goals

The Department of Energy's Federal Energy Management Program (FEMP), as mandated by Congress, leads the effort to reduce energy consumption and related costs within the federal government. FEMP's varied technical and finance assistance programs aid agencies in identifying, financing, and implementing projects that cost-effectively incorporate energy efficiency, water conservation, and renewable energy technologies into federal facilities.

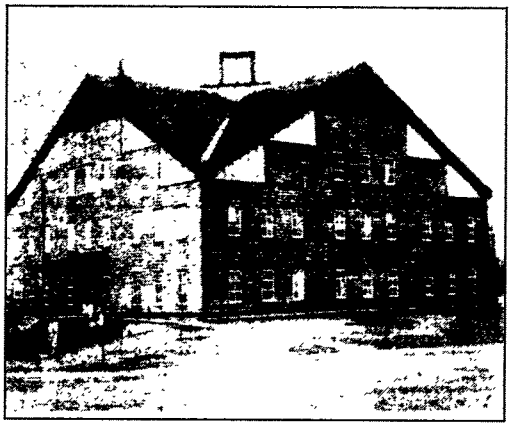
Between 1985 and 1997 the efforts of FEMP and other federal agencies have reduced energy consumption in government buildings by 17% in terms of Btu per square foot—reaching more than halfway to the federal goal of a 30% reduction by 2005. By promoting responsible energy management and institutionalizing energy efficiency as a good business practice, FEMP is contributing to the nation's economic vitality and productivity while providing the environmental benefits of reduced fossil fuel consumption.

## The DOE Role

The Energy Policy Act of 1992 and Executive Order 12902 require federal agencies to reduce the energy use of buildings and facilities by 20 and 30 % in the years 2000 and 2005 respectively, compared to 1985 energy intensities. FEMP focuses the majority of its efforts on reaching these goals in the government's approximately 500,000 buildings.

FEMP has created and implemented a range of tools to aid federal agencies' energy savings activities. One of these, the Energy Savings Performance Contract (ESPC), provides a type of contract through which agencies use private capital to provide energy efficiency services and then pay for these services through energy cost savings. Newly introduced regional and technology-specific Super ESPCs make energy efficiency contracting even more efficient. Facility improvements made under these Super ESPCs are forecast to cut federal energy costs by more than $11 billion over the life of the projects. FEMP is currently working with agencies to develop more than 150 ESPC projects.

In addition to its assistance with project financing options, FEMP also develops analytical tools and information to assist federal agencies with identifying and selecting cost-effective energy projects and products. These tools include on-site energy and water audits, evaluating project proposals, providing up-front engineering and design support, and assisting in the measurement and verification of projects' actual energy savings.



A building slated for energy efficiency upgrades at the USCG base in Kodiak, Alaska.

FEMP's training and outreach programs have reached almost 18,000 federal energy managers since 1993, including more than 4,700 in fiscal year 1999. A recent survey documented that FEMP training workshops help attendees implement energy efficiency projects. After attending FEMP workshops, 98% of the attendees have implemented energy efficiency projects, including those who were either unaware of or still seeking information about energy efficient technologies prior to their workshop attendance. While there are many factors leading to project

implementation, this survey demonstrates a high correlation between attending FEMP workshops and the execution of energy-efficiency projects.

## Benefits and Costs

According to preliminary 1998 data reported annually by all federal agencies, DOE FEMP and federal energy management programs in other federal agencies have accomplished the following:

- Reduced the government's primary energy consumption for buildings, mobility, and industrial operations by 351.2 trillion Btu, or 19%, between 1985 and 1998.
- Reduced energy costs by $6.5 billion inflation-adjusted dollars.
- Avoided the atmospheric release of carbon from buildings and facilities-related energy consumption by 2.1 million metric tons.
- Contributed significantly to a gross reduction in building energy costs of more than $2.2 billion compared to 1985.
- Assisted the federal government in reducing its use of petroleum-based fuels for all purposes by 35.9%, and for use in buildings by 63.7%, since 1985.

DOE FEMP has served as a catalyst for DOE and other federal energy-savings activities on a relatively modest budget. In FY1999, DOE FEMP spent just $23.8 million. From 1985 to 1999, FEMP has spent $142.1 million inflation-adjusted dollars.

The activities of FEMP and other federal energy management programs benefit not only the government's bottom line, but also the nation's economic vitality. To meet the 30% energy reduction goal by 2005 will require the investment of nearly $5 billion to repair or replace aging equipment in buildings. This investment will result in lower energy costs and more efficient operations for government agencies. These dollar savings may be used to invest in other federal activities and to reduce the federal deficit.

Generally, each dollar invested in energy efficiency results in savings of four dollars over a project's life, divided equally between the government and the private company if financed by the private company. This level of investment will create approximately 15,000 new jobs, reducing unemployment and contributing to the nation's economic vitality. Energy-efficiency and renewable-energy projects are an untapped economic resource and federal facilities comprise vast resource fields for job-creating economic activity in the construction, engineering, manufacturing, and financing industries.

Improving the energy efficiency of federal facilities also bestows environmental benefits on the nation: reduced energy demand lessens the atmospheric pollution emitted when electricity is generated; reduced water consumption lessens the stresses placed on aquatic ecosystems; and use of renewable energy technologies can completely eliminate point-of-generation pollution.

## For More Information

For more information on FEMP's energy-related activities, please visit their website at :

http://www.eren.doe.gov/femp

## Renewable Energy Technologies in Federal Facilities

With the goals of reducing energy consumption, showcasing renewable energy technologies, and enhancing the experience of visitors, DOE's Federal Energy Management Program (FEMP) and Office of Power Technologies (OPT) have teamed with the National Park Service (NPS) to install solar technologies at sites across the nation. This partnership provides park service facilities with energy at relatively low cost and with minimal adverse impacts on the environment. As Gary Candelaria, Pinnacles National Monument Superintendent, attests: "The PV [photovoltaic] system does everything we designed it to do, and it costs a fraction of what we used to pay each month to operate and maintain the diesel generators it replaces."

## The DOE Role

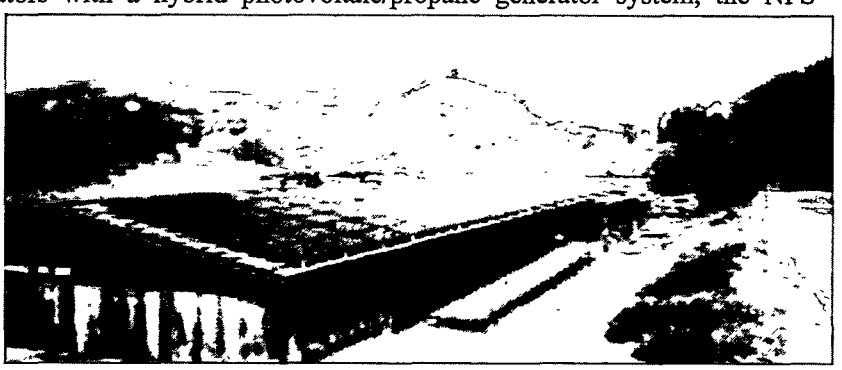
DOE FEMP employed a broad range of resources to ensure the success of the renewable-energy installations at Pinnacles and Chickasaw national parks in California and Oklahoma. In 1994, DOE's Sandia National Laboratories surveyed existing NPS photovoltaic systems, analyzed the site's electrical loads, conducted a solar resources assessment, summarized the power options available, recommended installation of a hybrid photovoltaic system, and then worked with NPS staff to develop an installation and operation plan. Sandia's technical assistance was funded by DOE at a cost of $60,000. At Chickasaw, FEMP liaisons from the National Renewable Energy Laboratory (NREL) conducted the initial feasibility study, prepared project specifications, reviewed the evolving design, and conducted final inspections on the completed system. FEMP provided $10,000 to enlist the aid of the NREL liaisons.

FEMP works within the federal government to encourage the use of renewable technologies by providing technical support and creative alternative-financing mechanisms that allow economically sound installation of renewable energy technologies. The benefits of this work are seen in the energy savings realized at the Pinnacles National Monument and Chickasaw National Recreation Area, described below. These two are only a small sample of the savings that are being, or could be, realized in other locales. In FY 1998 FEMP funded 30 renewable-energy projects out of more than 75 proposals. Total funding for the projects was $1.9 million. All of these projects will pay for themselves in less than 10 years.

## Benefits and Costs

**Benefits at Pinnacles National Monument.**

Pinnacles National Monument's decision to "go solar" was prompted by quality of life issues as well as cost. By replacing diesel generators with a hybrid photovoltaic/propane generator system, the NPS significantly reduced noise and pollutant emissions. These modifications have substantially improved the visitor experience. The installed hybrid system consists of a 9.6-kW photovoltaic array, a 200-kWh bank of flooded lead-acid batteries, a 20-kW propane-powered generator, and a modular inverter configuration.



The new system provides 100% of site power requirements from May through September and 30% during the winter months. Use of the photovoltaic array will reduce propane consumption by 162,000 gallons over 20 years, cutting annual fuel costs from $12,000 to $2,000, an 83% reduction. The system, including all energy-efficiency measures and installation, cost $150,000. It has a simple payback period of seven years, and is projected to save the park service $16,000 to $18,000 per year. The hybrid system also reduces atmospheric emissions: 135 tons of $CO_2$, 6,875.8 pounds of $NO_x$, and 342.9 pounds of $SO_2$ less than the emissions of the diesel generator sets.

**Benefits in Chickasaw, Oklahoma National Recreation Area.**

In an effort to lessen adverse effects on the local environment and save money at the same time, the National Park Service installed solar collectors at three comfort stations within Chickasaw to provide solar-heated water for showering, lavatories, and cleaning. The systems, totaling 872 square feet of solar collectors, produce about 37,000 kWh of solar heat annually and provide 95°F water year-round with 93 to 96% reliability. In addition to the systems' technical advantages, user demand patterns at the park closely follow the amount of available sunlight, increasing overall system efficiency.

These systems, designed to save energy, reduce emissions, and lower the park service's operating and maintenance cost burden, cost $31,700 to install, and have a simple payback period of nine years. The systems reduce purchased energy consumption by 36,982 kWh or 126 million Btu per year, saving $2,219. In addition to the three installed systems, 20 more are planned for the site.

**For More Information**

For information on work conducted at Pinnacles National Monument, please visit:

http://www.eren.doe.gov/femp/techassist/530_pinnacles.html.

For information on the Chickasaw NRA project, please visit:

http://www.eren.doe.gov/femp/newsevents/femp_focus/may97_park.html

## FEMP Lamp Swap

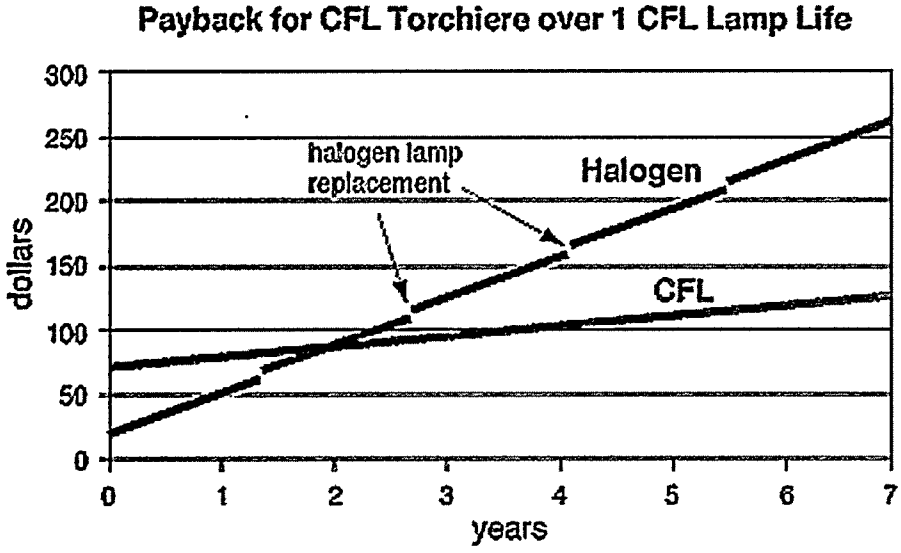
In January 1998, the Federal Energy Management Program (FEMP) coordinated a program at Bolling Air Force Base in Maryland in which on-base housing residents traded in halogen torchiere lamps for torchieres lighted by compact fluorescent lamps (CFLs), which were provided at no cost by DOE. The drive behind the swap was two-fold: decrease energy consumption by switching to energy-efficient CFLs, and increase the safety of on-base housing by removing the type of halogen torchieres that have been implicated in 260 fires and 12 deaths in the United States.

If one million advanced CFL torchieres were purchased by consumers instead of halogen torchieres, the estimated energy cost savings would be $27.4 million annually (343 million kWh energy savings) or $192 million (2.4 billion kWh) over the seven-year life of the lamps. Estimates are that 200,000 CFL torchieres were sold in 1998.

## The DOE Role

FEMP leads the effort to reduce energy use and costs in the federal government. Of all the residential property owned by the government, 90% is military housing. The Bolling AFB torchiere swap was coordinated by DOE, Bolling leadership, and the Department of Defense (DoD), in partnership with DOE's Lawrence Berkeley National Laboratory and the Alliance to Save Energy, a non-profit organization. DOE invested roughly $300,000 between 1995 and 1997 to research and develop the technology and spent $ 7,500 (150 lamps at $50 each) to buy the CFL torchieres provided at no charge to residents. The Bolling lamp swap has the potential to save 1.2 billion Btu—a savings of nearly $29,000 over the lamps' seven-year lifespans.

## Benefits and Costs

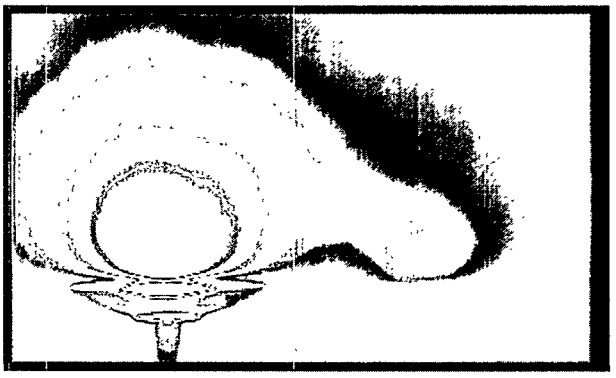



Compact fluorescent torchieres produce 25% more light than halogen torchiere-style lamps while using just 20% of the electricity. Despite their higher initial cost (CFL torchieres can cost $70 compared to $20 for halogen torchieres), the more efficient CFLs have a lifespan five times that of halogen lamps, so each lamp can save $192 in energy costs over its lifetime.

The energy-efficiency of CFLs provides safety benefits to the consumer as well. Because they consume significantly less electricity, the bulb temperature doesn't exceed much more than 100°F. Halogen bulb

temperatures can reach over 1,000°F. These extreme temperatures can cause fabrics, such as drapes, to ignite, and have been implicated in starting 260 fires and causing 12 deaths in the United States alone. Just one week before implementing the swap, a halogen lamp was implicated in a fire at Bolling AFB. No one was injured in the incident.

Gene Foley, lighting and appliances program manager at the Alliance To Save Energy, said, "These new fixtures will do more than light the homes at Bolling. They will save tax dollars, cut pollution, and ensure the safety of those who use them."



Halogen CFL

**For More Information**

For more data and information on halogen torchieres, please visit:

http://eetd.lbl.gov/BTP/torchiere.html

## FEMP Helps Government Agencies to Buy Energy-Efficient Products

The federal government spends an estimated $12 billion per year purchasing energy-related products, and $8 billion a year on energy itself. Executive Order 13123, issued in June 1999, aims to reduce the costs and environmental impacts of federal energy usage by cutting energy consumption by 35% by 2010. The Federal Energy Management Program (FEMP) has an array of programs designed to meet this goal. One activity alone—purchasing and using energy-efficient equipment—has the potential to meet 20% of the year 2010 energy-savings goals. FEMP spent approximately $600,000 in FY1999 to provide government purchasers with reliable information on the energy efficiency of commonly purchased products, and to train purchasers to identify energy-efficient products in a range of categories.

### The DOE Role

Executive Order 13123 requires federal agencies to, where cost-effective, purchase "ENERGY STAR® and other energy efficient products. Where ENERGY STAR® labels are not yet available, agencies shall select products that are in the upper 25% of energy efficiency as designated by FEMP." Twenty-two agencies signed the Procurement Challenge in 1995. FEMP has the lead role in advising agencies of these provisions and assists agencies in identifying energy-efficient products through publication of *Product Energy Efficiency Recommendations*. The 33 *Recommendations* available currently range from large electric chillers to light bulbs. The *Recommendations*

- identify the efficiency level that complies with the upper 25% requirement,
- identify federal supply sources that offer efficient products,
- suggest ways for buyers to identify efficient products when buying from commercial sources, and
- present cost-effectiveness examples for products.

The *Recommendations* are a popular and effective tool for energy managers. About 2,700 *Recommendations* binders have been distributed since the first printing in 1997, about two-thirds of them to federal employees. Almost half of the recipients responding to a November 1998 customer survey reported that they have implemented energy- or water-saving projects during the past two years, and that their decisions were influenced in part by the *Recommendations*.

FEMP is also an active partner with the U.S. Environmental Protection Agency (EPA) in the ENERGY STAR® labeling program, working with EPA to improve the efficiency of products ranging from office equipment to electrical transformers. By influencing purchasers to think in terms of energy efficiency, the government's bulk purchasing power can send a strong signal to manufacturers to produce more efficient products at a more competitive cost, thus making them more attractive to the private sector.

### Benefits and Costs

The Army Corps of Engineers and the Navy have taken a comprehensive approach to instituting FEMP's *Recommend-ations*. Each of these agencies has "hard-wired" several of FEMP's recommended levels into their guide specifications for new construction and major renovation work. The guide specifications are the template used by architecture and engineering firms to develop actual project specifications. Among the products affected are electric chillers, distribution transformers, motors, and fluorescent tube lighting. The Army Corps and Navy are responsible for the majority of the roughly $6 billion per year in DoD construction.

The success of the Federal Procurement Challenge is based on the aggregate savings of many individual purchasing decisions. For example, incorporating the *Recommendations* into their business-as-usual practices, federal agencies can realize cost and energy benefits from merely replacing conventional fluorescent lights at the end of their lives with energy-saving ballasts and bulbs. These benefits are considerable when applied on the scale of an entire building, and even greater when one considers the numbers of fluorescent lamps in government buildings across the nation. Similar savings are achievable for the range of items documented in FEMP's *Recommendations*.

*Fluorescent Tube Lamp Cost-Effectiveness Example*

| Performance | Base Model | Recommended Level | Best Available |
|---|---|---|---|
| **Lamp and Ballast Type** | T12, 34 watts, magnetic ballast | T8, 32 watts, electronic ballast | T8 32 watts, electronic ballast |
| **Actual Light Output, with Ballast** | 4738 lumens | 5018 lumens | 5256 lumens |
| **Input Power** | 82 watts | 62 watts | 57 watts |
| **Annual Energy Usage** | 295 kWh | 223 kWh | 205 kWh |
| **Annual Energy Cost** | $17.70 | $13.40 | $12.30 |
| **Annual Energy Cost Savings - 2 Lamps & Ballast** | — | **$4.30** | **$5.40** |

## For More Information

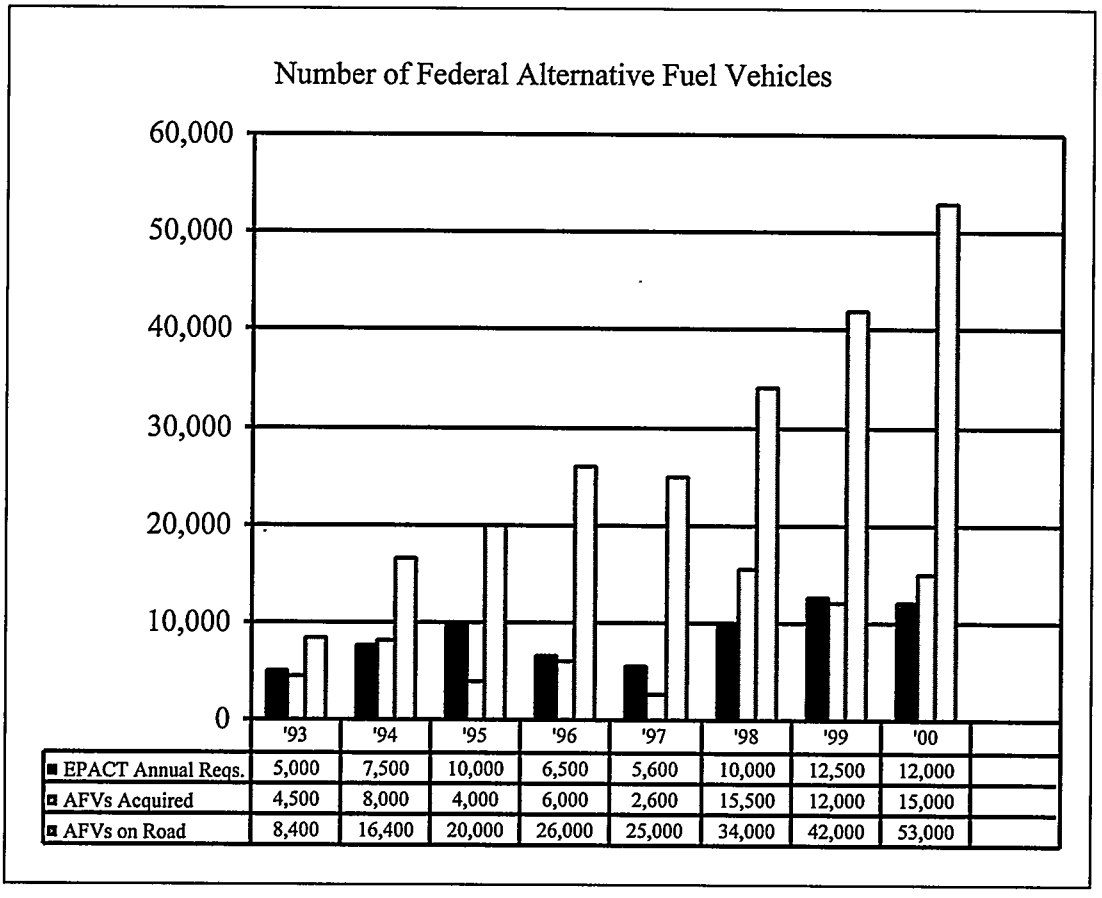
For more information regarding FEMP's Procurement Challenge, please see:

http://www.eren.doe.gov/femp/procurement/challenge.html

## Federal Fleet Alternative Fuel Acquisition Program

One of the goals of the Energy Policy Act of 1992 (EPACT) is to displace 10% of petroleum fuel used in the transportation sector with replacement fuels (e.g., natural gas) by the year 2000. Successful introduction and commercialization of alternative fuel vehicles (AFVs) and advanced technology vehicles with significantly improved fuel economy are necessary to achieve reductions in oil consumption and environmental emissions from the transportation sector. The U.S. Department of Energy (DOE) is making steady progress in carrying out the provisions of EPACT.

The DOE and other Federal agencies have been working to promote the purchase and use of AFVs in accordance with Title III of EPACT. In addition to providing reductions in U.S. petroleum use, the acquisition and use of AFVs by Federal agencies will help demonstrate the practicality of alternative fuel technologies on a substantial scale. These acquisitions are also designed to accelerate the development of an alternative fuel refueling infrastructure. Over time, operation of AFV's by Federal and other regulated fleets should provide the critical mass necessary to motivate U.S. industry to product alternative fuels and vehicles at competitive prices.




| | '93 | '94 | '95 | '96 | '97 | '98 | '99 | '00 |
|---|---|---|---|---|---|---|---|---|
| EPACT Annual Reqs. | 5,000 | 7,500 | 10,000 | 6,500 | 5,600 | 10,000 | 12,500 | 12,000 |
| AFVs Acquired | 4,500 | 8,000 | 4,000 | 6,000 | 2,600 | 15,500 | 12,000 | 15,000 |
| AFVs on Road | 8,400 | 16,400 | 20,000 | 26,000 | 25,000 | 34,000 | 42,000 | 53,000 |

The potential for using replacement fuels in the United States is very high. Analysis indicates that currently authorized Federal, state, and local alternative fuel programs alone could displace roughly 3% of gasoline fuel use projected for 2010. In addition, current estimates suggest that the entire transportation market could support replacement of as much as 30 to 38% of the light-duty vehicle fuels by the year 2010.

The DOE AFV deployment program is divided into four complementary program areas: Clean Cities, Testing and Evaluation, EPACT Replacement Fuels Program, and Advanced Vehicle Competitions. The Federal Fleet AFV Acquisition Program is included in the Testing and Evaluation program area. Total spending in this account was approximately $3 million for both FY 1998 and FY 1999, of which nearly $1.4 million was spent on the Federal Fleet AFV program each year. This includes $1 million a year to buy-down 50% of the incremental cost of electric vehicles procured by Federal agencies, as directed in Executive Order 13031 of 1996. The incremental cost of acquiring other AFVs was borne by the participating Federal Agency.

## Benefits and Costs

Selected accomplishments to date are summarized below.

•Promoted the acquisition of more than 34,000 AFVs by Federal fleets – nearly 80% of the EPACT requirement of 44,600 through fiscal year 1998. 52% of the AFVs are compressed natural gas vehicles and 47% are M-85 or E-85 vehicles.

•Used 4.2 million gasoline-gallon-equivalents of alternative fuels in Federal fleets in 1997.

•Initiated a pilot program in Washington, D.C. to loan electric vehicles (EVs) to Federal fleets for 30 days at no cost and with no commitment. DOE pays for the loaned EVs to give Federal fleet managers the opportunity to test the technology and encourage them to acquire EVs.

•Expanded EV Loaner Program started in Washington, D.C. to include Atlanta, Boston, Los Angeles, San Diego, and Norfolk/Richmond/Northern Virginia.

•Established an EV Incremental Cost Buy-Down Program for Federal fleets acquiring EVs, which, in conjunction with the EV Loaner Program, has resulted in the placement of 140 EVs by Federal fleets for FY 1999.

## Future Activites

- Establishing the Federal Fleet Focus Cities Program to support alternative fuel infrastructure through the coordinated, concentrated acquisition of Federal AFVs and use of alternative fuel in Federal AFVs in six designated cities.

- Assisting in the procurement of more than 10,000 AFVs for Federal fleets in FY 1999.

- Supporting the procurement of 12,500 AFVs annually for Federal fleets in FY 2000 and beyond.

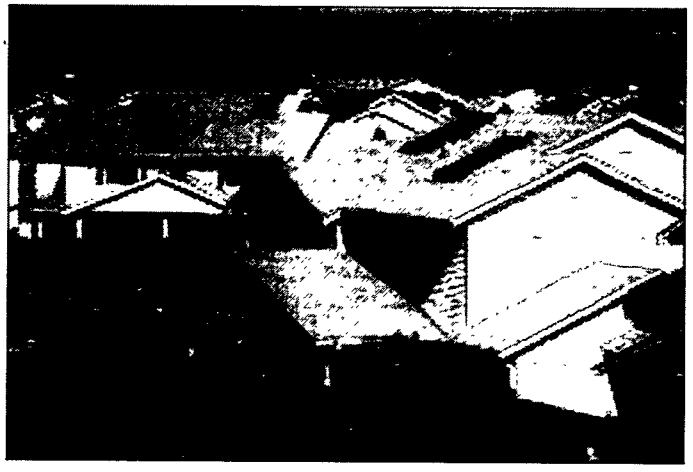
## For More Information:

http://www.afdc.doe.gov

National Alternative Fuels Hotline - 1-800-423-1DOE

## Million Solar Roofs Initiative

Million Solar Roofs (MSRI) is an initiative to install solar energy systems on one million U.S. buildings by 2010. MSRI includes two types of solar energy technology – photovoltaics (PV) that produce electricity from sunlight, and solar thermal systems that produce heat for domestic hot water, space heating or heating swimming pools.



**Solar hot water systems at the Navy's Moanalua Terrace family housing project in Hawaii.** Hawaiian Electric Co., Inc NREL/PIX05573.

### The DOE Role

DOE leads this effort in partnership with financial institutions, the building industry, utilities, energy service companies, the solar energy industry, state and local governments, Federal agencies, and non-governmental organizations. Together they work to remove market barriers to solar energy use and develop and strengthen demand for solar energy products and applications by developing new and existing financing options, leveraging resources, coordinating Federal agency support and sharing information with MSRI partners. DOE does not typically pay for the installation of solar systems under MSRI. The Department of Energy, through its network of Regional Offices (RO's) coordinates and provides support for the State and Local Partnerships in their area. This might include the following:

- Access to the Million Solar Roofs Small Grants program for State and Local Partnerships;
- Assistance in accessing low-cost loans, buy-down grants, and other financial assistance;
- Training, technical assistance, and information from DOE's RO's, program staff and national labs;
- Recognition on a national, regional, and local basis;
- Linkage with solar energy businesses, associations, and related industries that can provide assistance to local partnerships and others interested in solar energy applications.

### Benefits and Costs

MSRI received $1.5 million in funding in fiscal year 1999. Since the announcement of the Initiative in June, 1997, thirty-seven State and Local Partnerships have been formed across the country to develop local markets for solar energy systems. Together they have preliminary plans to install more than 900,000 solar energy systems on buildings by 2010. At the end of 1998, approximately 30,000 solar systems had been installed, including grid-connected and off-grid PV systems, solar hot water heaters and systems to heat swimming pools. A registry to track installed systems will become operational in 1999. A selection of additional accomplishments are highlighted below.

The U.S. Navy installed 136 solar hot water heaters in Phase II of the Moanalua Terrace Navy Family Housing project, in Oahu, Hawaii. The systems cost $235,000 to install and save $34,000 in energy costs

annually. Over their lifetime these 136 systems will save $680,000 in energy costs, 16.5 million pounds of CO2, 50,785 pounds of $NO_x$, and 54,550 pounds of $SO_2$. Another 516 systems are being installed in Phases III and IV.

In June 1998, Wisconsin Public Service Corporation (WPSC) installed a 4 kW, grid-connected, roof mounted PV system on East De Pere High School. The East De Pere PV system is the sixth to be installed on an area high school under their Wisconsin Public Service Community Foundation's SolarWise for Schools Program. In addition, WPSC received support through the Utility PhotoVoltaic Group directed TEAM-UP program. By using the PV system, 7,075 pounds of coal will not be used each year. This amounts to an annual reduction in emissions of 12,458 pounds of $CO_2$, 58 pounds of $SO_2$, 67 pounds of $NO_x$, and 2 pounds of particulates.

In 1998, the Western Area Power Administration installed a 38 kilowatt grid-connected PV system on its Elverta, California Maintenance Facility. The system generates 67,500 kilowatt hours of electricity per year and over its 20 year lifetime, the system will reduce emissions by 2,300 tons of $CO_2$, 8.7 tons of $NO_x$, and 16.4 tons of $SO_2$.

## Potential Future Benefits

One million solar energy systems could result in the sale of 2500 MW of PV and solar water heating systems by 2010, reduction of $CO_2$ emissions by 3.5 million tons and the creation of 71,500 jobs.

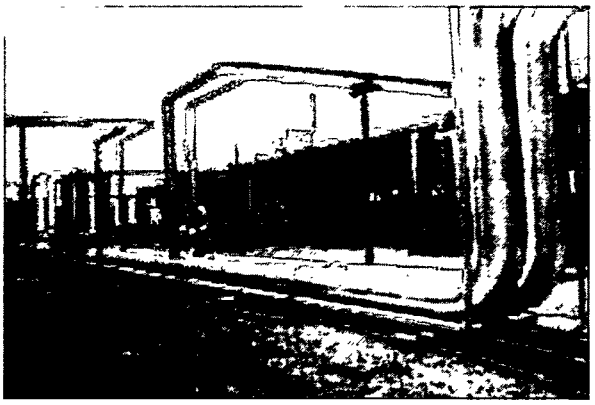
## For More Information

Visit the MSRI web site at http://www.MillionSolarRoofs.org

## Climate Challenge

Climate Challenge is a joint, voluntary effort of DOE and the electric utility industry to reduce, avoid, or sequester greenhouse gases. Utilities, in partnership with DOE, implement cost-effective activities that are specified in partnership accords, which are agreements between DOE and individual electric utilities.

Activities include efficiency improvements in end use, distribution, transmission, and generation; increased use of energy-efficient electro-technologies; fuel switching to lower carbon fuels such as natural gas, nuclear, or renewable energy; transportation actions, including greater use of natural-gas-powered and electric vehicles; forestry actions; recovery of methane from landfills and coal seams; and the use of fly-ash as a cement substitute.



**Sierra Pacific Power is purchasing power from this geothermal plant in Stillwater, Nevada. Geothermal plants in the U.S. generated 16.3 billion kilowatt hours of electricity in 1997.** Sierra Pacific NREL/PIX07208

## The DOE Role

DOE has been active in negotiating participation accords and reviewing existing accords. DOE also urged Department of Treasury officials to allow energy-conservation expenditures by utilities to be treated as business expenses. In April 1995, the Internal Revenue Service concluded that utility expenditures on demand-side management programs can be deducted from corporate income taxes as business expenses. DOE has also supported government/utility joint ventures in energy efficiency and renewable energy to increase market penetration and reduce costs. This includes supporting the Geothermal Heat Pump Consortium, the Utility PhotoVoltaic Group, and the Consortium for Energy Efficiency. DOE has also encouraged large purchases of efficient products by assisting buyers' groups through the Volume Purchase Program and coordinating alliances with major manufacturers, retailers, and utilities to promote and expand the market for high-efficiency commercial and residential clothes washers and dryers.

## Benefits and Costs

Climate Challenge received a total of $0.95 million in funding from fiscal years 1995 to 1999. A total of 124 participation agreements have been signed, representing 641 utilities that together account for 71% of utility carbon emissions. Utility commitments carried out under Climate Challenge are estimated to result in the reduction of 47.6 million metric tons of carbon in 2000. The estimate is conservative, as it does not include reductions not yet quantified, nor the effects of nine industry-wide utility initiatives. Some examples of actions taken by utilities include the following:

The utility industry developed nine Climate Challenge initiatives for collective utility action. The initiatives include venture capital funds under the EnviroTech charter, with over $50 million committed to accelerate commercialization of renewable-energy technology and energy-efficient electrotechnologies; the Earth Comfort Program, to increase annual sales of energy-efficient geothermal heat pumps from

40,000 to 400,000; the Utility Forest Carbon Management Program, with over $2 million committed to funding several domestic and international projects through the non-profit UtiliTree Carbon Company; and the International Utility Efficiency Partnerships, which is currently developing or evaluating carbon-saving projects in at least twelve countries.

In northern Nevada, Sierra Pacific Power is purchasing geothermal-generated power. By displacing generation from conventional coal units, these geothermal contract purchases reduce $CO_2$ emissions by about 400,000 tons per year, with reductions in the year 2000 expected to be nearly 600,000 tons of $CO_2$.

In the first market-based trade between electric utilities, Niagara Mohawk Power Corporation exchanged 1.75 million tons of $CO_2$ reductions for Arizona Public Service Company's 25,000 tons of sulfur dioxide allowances. Niagara Mohawk donated the sulfur dioxide allowances, which have an established market value under the 1990 Clean Air Act Amendments, to a non-profit environmental group to be retired. This exchange reduces both acid rain and greenhouse gas emissions.

Nearly all utilities that operate fossil-fuel-fired generators are committed to efficiency improvements. Tampa Electric Company and Sierra Pacific cite their participation in DOE's Clean Coal Technology Program as a way to more efficiently generate electricity and concurrently reduce $CO_2$ emissions by 25% (compared to a conventional power plant).

American Electric Power (AEP) committed to plant 15 million trees on 20,000 acres of company-owned land. Several species of pine and hardwood are being planted, enhancing the value of these lands as a diverse forest and improving the overall wildlife habitat. Over a 30-year project period, AEP estimates that carbon sequestration will equal about 1.63 million tons of $CO_2$. AEP is also investigating cofiring of biomass with coal.

A significant effect of the Climate Challenge program is the shift in thinking of electric utility management and strategic planners to include the mitigation of greenhouse gas emissions into their corporate culture and philosophy.

## Potential Future Benefits

Utility commitments under Climate Challenge are expected to reduce 47.6 MMTC of $CO_2$ emissions in the year 2000.

## For More Information

Climate Challenge web site: http://www.eren.doe.gov/climatechallenge/

## High Temperature Materials Laboratory

The government's primary role in research and development is to support long-range, high-risk activities where breakthroughs offer large potential payoffs to the nation. The High Temperature Materials Laboratory (HTML) at Oak Ridge National Laboratory gives researchers from industry, academia, and federal laboratories access to some of the most advanced materials characterization equipment in the world. Sponsored by DOE's Office of Transportation Technologies, HTML and its User Program conduct world-class materials research focused on solving high-temperature and advanced materials problems that limit the efficiency and reliability of advanced energy-conversion systems (diesel engines, for example).

Because the User Program is intended to promote research that will help the United States meet technological challenges from foreign competitors, participants conducting research can use the facilities at no cost, provided the research results are openly published for the benefit of U.S. scientific and industrial communities.

Facility users range from industry giants like Ford Motor Company and Dow Chemical Company to small start-up companies that lack sufficient capital to invest in advanced instrumentation. For example, LoTEC, Inc., a Salt Lake City manufacturer of low-thermal-expansion ceramic components, used the HTML facility in 1992 when it had only seven employees. One of the company's research engineers spent six months at ORNL using a wide range of HTML's capabilities, including dilatometry, electron microscopy, x-ray diffraction, and laser thermal diffusivity. The instrumentation was used to resolve several problems related to formulation and heat treating of low-thermal-expansion ceramic components for engine exhaust manifolds.

Ford Research Laboratory engineers recently used the Thermophysical Properties User Center to evaluate the thermophysical characteristics of new lightweight materials for automobile brakes. Once perfected, such materials will reduce the mass of automotive vehicles and increase their fuel efficiency, which will in turn reduce pollution. Use of HTML's flash thermal diffusivity equipment and differential scanning calorimeter allowed Ford engineers to characterize the properties and performance of these candidate automotive brake materials at room temperature and at high temperatures. The thermophysical property data collected at HTML was used in finite-element and heat-transfer models to evaluate use of an aluminum-metal-matrix composite for brakes. It also allowed Ford engineers to get hands-on experience with advanced equipment before deciding whether to invest in a purchase.

The HTML facility has received an average of about $5 million per year in DOE funding in recent years. This funding has enabled HTML's user centers—Materials Analysis, Mechanical Characterization and Analysis, Machining and Inspection Research, Thermophysical Properties, Diffraction, and Residual Stress—to complete more than 800 projects over an eleven-year period.

## APPENDIX A

## DETAILS ON THE EERE SUCCESS METRICS

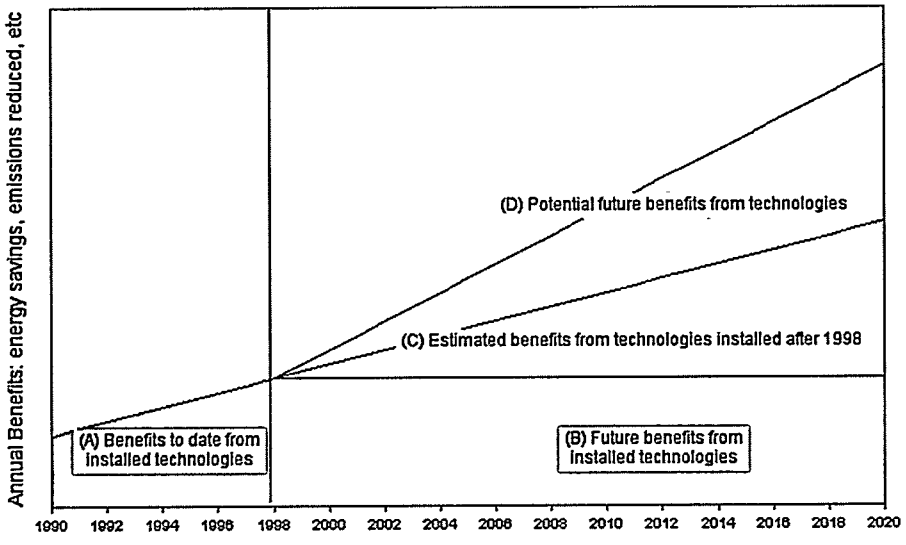
The summary analysis is based on 20 accomplishments (11 R&D successes and nine field verification, deployment, and outreach successes), for which quantified benefits could be measured for products and technologies installed to date. Data on estimated future benefits for emerging technology programs were 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. In some cases, an accomplishment describes the benefits and costs accruing from one year of a program's operation. In other cases, the benefits and costs are cumulative for the entire life of the program. In some instances "energy cost savings" include only energy savings that have been realized to date. In other instances, the estimates incorporate the savings that will occur throughout the operating lifetimes of equipment installed to date. There are differences in the use of nominal or real dollars, the assumed discount rate, and so on. These differences are limited somewhat by the EERE Programs' use of common references such as price forecasts and other assumptions in publications such as the Energy Information Administration's *Annual Energy Outlook.* Because of these differences, we have made no attempt to compare aggregate costs and benefits across 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. However, limited resources did not permit extensive recalculations based on standardized assumptions.

Time horizons for measuring benefits are shown below.

**EERE Program Benefit Measurement Horizons**



Section A shows the **benefits to date from commercialized technologies that were installed prior to 1999**. These are annual benefits from EERE technologies currently installed the marketplace. These benefits expand over time as market penetration increases. The time horizon used in this report for describing these benefits typically begins with the year of market introduction and continues through 1998.

Section B shows **the future benefits from commercialized technologies that were installed prior to 1999**. This is a characterization of future benefits from EERE technologies currently installed and that continue to produce benefits. The time horizon for these benefits is based on the lifetime of the particular technology. That lifetime might be quite short (*e.g.,* the 7-year lifetime of a compact fluorescent torchiere) or quite long (*e.g.,* the 30-year operational life of a new wind turbine).

Section C shows **estimated future benefits from technologies installed after 1998**. These future benefits come from two sources: (1) the greater market penetration of previously commercialized EERE technologies and (2) emerging technologies that will enter the market in future years. The magnitude of these benefits is tied to the amount of funding projected for EERE programs.

Section D shows **the potential future benefits from technologies**. This represents what the full market potential could be for EERE technologies if all market imperfections were overcome. The estimate includes the effect of stock turnover and does not assume that the new technologies will accelerate the retirement of operating equipment unless the life-cycle economics are sufficiently compelling.

The level of DOE R&D investment and the actual benefits from the successes showcased in this report are summarized in Table 1. A finer breakdown of these estimates of costs and benefits is provided in Tables 2, 3, and 4. These metrics represent a combination of cumulative and annual numbers and are based on technologies installed to date.

**Table 1. Summary Success Metrics for Recent EERE Accomplishments[a]**

| Metric | R&D Successes (N=11) | Field Verification, Deployment, and Outreach Successes (N=9) | Totals |
|---|---|---|---|
| DOE R&D Investment (million $) | $230 | $480 | $710 |
| | | | |
| Energy Saved (trillion Btu) | 5,050 | 500 | 5,550 |
| Energy Replaced (trillion Btu) | 110 | 1,580 | 1,690 |
| | | | |
| Energy Cost Savings (million $) | --** | --** | --** |
| Value of Energy Displaced (million $) | --** | --** | --** |
| | | | |
| Carbon Emission Reductions (MMTC) | 89 | 13 | 102 |

[a]See Tables 2 and 3 for details.

**Because the dollar values that comprise these totals are not standardized to a common base year, totals are not provided. Based on the 5,550 trillion Btu of energy savings and the cost to consumers of an average Btu of energy consumed in 1998, the value of energy saved for all 20 successes is estimated to be $30 billion ($1998).

## Table 2. Metrics for R&D Successes[1]

| DOE Technology or Program | DOE R&D Investment (million $) | Energy Saved or Replaced (tBtu) | Energy Cost Savings (million $) | Carbon Emission Reductions (MMTC) | Other Benefits |
|---|---|---|---|---|---|
| **Buildings** | | | | | |
| 1. Compact Fluorescent Torchieres | $0.3 | 5 | $41 | 0.1 | Fire safety |
| 2. Ozone-Safe Refrigerants | $15 | 2,000 | $16,000 | 30.6 | Ozone protection |
| 3. Spectrally Selective Glazings | $3.5 | NA | NA | NA | |
| **Industry** | | | | | |
| 4. Oxygen-Enriched Combustion | $1 | 13 | $28 | NA | 80% $NO_x$ reduction: 25% PM reduction |
| 5. Inventions and Innovations Program | $84 | 80 | $190 | 1.6 | Job creation |
| **Transportation** | | | | | |
| 6. Lightweight Materials (aluminum only) | $40 | 750 | $7,200 | 15 | |
| 7. Diesel Engines | $45 | 2,180 | $16,800 | 38.2 | |
| **Power** | | | | | |
| 8. SEGS Parabolic Trough Plants | $3.2 | NA | NA | NA | $4M savings in annual O&M |
| 9. Wind Turbine Technology | $12 | 110 | *$246 | 2.1 | |
| 10. Geothermal Heat Pumps | $24 | 25 | $980 | 1.7 | |
| 11. Transpired Solar Collectors | $2 | 2.2 | *$10 | 0.03 | |
| **Totals** | $230 million | 5,170 tBtu | --** | 89.3 MMTC | |

[1] Metrics are a combination of cumulative and annual numbers, and impacts to date over the lifetimes of installed products. See the end notes for an explanation of the metrics for each technology or program. MT = metric tons. MMTC = million metric tons. PM = particulate matter.

*Represents the cost of displaced energy, where oil or other fossil fuels have been displaced by cleaner sources of energy.

**Because the dollar values that comprise these totals are not standardized to a common base year, totals are not provided.

**Table 3. Metrics for Field Verification, Deployment, and Outreach Successes[1]**

| DOE Technology or Program | DOE R&D Investment (million $) | Energy Saved or Replaced (tBtu) | Energy Cost Savings (million $) | Carbon Emission Reductions (MMTC) | Other Benefits |
|---|---|---|---|---|---|
| **Buildings** | | | | | |
| 12. Weatherization Program | $125 | 108 | $550 | 1.63 | Health, safety |
| 13. Promoting Buildings Standards | $144 | 154 | $1,120 | 3.55 | |
| 14. Rebuild America | $7 | 32 | $162 | 0.40 | New jobs |
| **Federal Energy Management** | | | | | |
| 15. Energy Savings Performance Contracts | $8 | NA | NA | NA | NA |
| **Industry** | | | | | |
| 16. Energy Technologies at Bethlehem Steel | NA | 2 | $8 | 0.01 | 171 MT $NO_x$<br>395 MT $SO_x$<br>2 MT VOCs |
| 17. Industrial Assessment Centers | $47 | 71 | $300 | 1.51 | |
| 18. Motor Challenge | $6 | 131 | $2 | 0.01 | 18 MT $NO_x$<br>16 MT $SO_x$ |
| **Transportation** | | | | | |
| 19. Alternative Vehicles in Clean Cities | $15 | 48 | *$900 | 0.40 | |
| 20. Ethanol Fuels Program | $130 | 1,530 | *$12,000 | 5.00 | |
| **Totals** | $482 million | 2,080 tBtu | --** | 12.5 MMTC | |

[1] Metrics are a combination of cumulative and annual numbers, and impacts to date over the lifetimes of installed products. See the end notes for an explanation of the metrics for each technology or program. MT = metric tons. MMTC = million metric tons. PM = particulate matter.

*Represents the cost of displaced energy, where oil or other fossil fuels have been displaced by cleaner sources of energy.

**Because the dollar values that comprise these totals are not standardized to a common base year, totals are not provided.

**Table 4. Metrics for Emerging R&D Successes[1]**

| DOE Technology or Program | DOE R&D Investment (million $) | Energy Saved or Replaced (tBtu) | Energy Cost Savings (million $) | Carbon Emission Reductions (MMTC) | Other Benefits |
|---|---|---|---|---|---|
| **Buildings** | | | | | |
| 21. High-efficiency refrigerators | $1 | 290 | $6,000 | 12.00 | |
| **Industry** | | | | | |
| 22. Combined heat and power | $33 | 27 | $160 | 0.65 | |
| 23. Lost foam metal casting | $2 | 37 | $78 | NA | 700,000 tons solid waste reduction |
| 24. Nickel Aluminides | $21 | 60 | $180 | NA | O&M savings |
| **Power** | | | | | |
| 25. Photovoltaic thin film partnership program | $102 | 17 | $54* | 0.25 | $Millions in exports |
| 26. Biomass gasifiers | $22 | 14 | $2* | 0.24 | |
| 27. High-temperature superconductivity equipment | $107 | 500 | $564 | 35.73 | Reduced $NO_x$ and $SO_x$ Emissions |
| **Totals** | $288 million | 950 tBtu | --** | 49 MMTC | |

[1] Metrics are a combination of cumulative and annual numbers, and impacts to date over the lifetimes of installed products. See the end notes for an explanation of the metrics for each technology or program. MT = metric tons. MMTC = million metric tons. PM = particulate matter.

*Represents the cost of displaced energy, where oil or other fossil fuels have been displaced by cleaner sources of energy.

**Because the dollar values that comprise these totals are not standardized to a common base year, totals are not provided.

## NOTES FROM TABLES 2, 3 AND 4

### R&D Successes

1. [Compact Fluorescent Torchieres] These metrics indicate the energy displacement, cost savings, and emission reductions that may be realized over the fluorescent bulb's expected 7-year lifetime. The benefits in 1998 are: 0.75 tBtu displaced, $4.8 million saved, and 0.01 MMTC reduced.
2. [Ozone-Safe Refrigerants] Figures shown represent cumulative energy displacement, energy cost savings, and carbon emission reductions for the period 1994-96. DOE R&D investment figure is cumulative from 1985 to 1998.
3. [Spectrally Selective Glazings] These metrics are not yet available. DOE R&D investment shown is cumulative from 1986 to 1996.
4. [Oxygen-Enriched Combusion] Energy displacement and energy cost savings are shown cumulatively from 1991 to 1997. The benefits in 1997 are: 3.4 tBtu displaced and $7.2 million saved. DOE R&D investment figure represents cost share of initial demonstration.
5. [Inventions & Innovations Program] Figures shown are DOE investment, energy displacements, energy cost savings, and carbon emission reductions from I&I program developments through the year 1996.
6. [Lightweight Materials] Figures show cumulative benefits through 1997 and are based upon weight reductions beginning in 1978. Dollar savings are "current dollars."
7. [Diesel Engines] Figures show cumulative benefits from 1983 to 1997. Dollar savings are "current dollars."
8. [SEGS Parabolic Trough Plants] Several of these metrics are not available. DOE R&D investment period is1992-1997.
9. [Wind Turbine Technology] Energy displacement, energy cost savings, and carbon emission reduction figures indicate energy displacement, savings, and emission reductions over the turbine's lifetimes. The benefits to date are: 1.3 tBtu displaced, $2.5 million displaced, and 0.024 MMTC reduced.
10. [Geothermal Heat Pumps] Energy displacement, energy cost savings, and carbon emission reduction figures indicate the potential energy displacement, savings, and emission reductions possible over the lifetimes of heat pumps installed from 1995 through 1998. DOE &RD investment shown is for years 1995 through 1998. Benefits to date for the same period are: 4.3 trillion Btus displaced, $34 million saved, 0.1 MMTC reduced.
11. [Transpired Solar Collectors] Energy displacement, energy cost savings, and carbon emission reduction figures indicate energy displacement, savings, and emission reductions possible over the lifetime of the collectors. The benefits to date are: 0.3 tBtu displaced, $1.2 million displaced, and 0.004 MMTC reduced.

### Field Verification, Deployment, and Outreach Successes

12. [Weatherization Program] DOE investment shown is for 1998 only. The program also leveraged an additional $198 million in funding. Energy savings are for the 20-year lifespan of the weatherization measures installed through 1996. 8,000 jobs were created.
13. [Promoting Buildings Standards] DOE investment shown is cumulative from 1980 to 1998. Energy displacement, cost savings, and carbon emission reduction data are for 1998.
14. [Rebuild America] DOE investment shown is over the period 1995 to 1998. Annual energy cost savings and annual carbon emission reductions are for 1999.
15. [Energy Savings Performance Contracts] DOE investment figure includes all ESPC and utility financing for 1999. Energy savings shown are cumulative for all projects over a 25 year period if the maximum value of contract authority in place by 2000 is used. Annual carbon emission reductions are estimated at the point in time when all ESPCs are in place.

16. [Energy Technologies at Bethlehem Steel] Energy displacement, cost savings, emission reduction, and other benefits figures realized on an annual basis at Burns Harbor from installation/operation of energy efficient equipment.
17. [Industrial Assessment Centers] Investment figure calculated over the period 1976 - present. Energy displacement, energy cost savings, and carbon emission reductions are annual savings and reductions to be realized by year 2000.
18. [Motor Challenge] DOE investment in FY1998 for entire Motor Challenge program. Energy displacement and cost savings are for a single year from 13 Motor Challenge Showcases. If replicated industry-wide, cost savings will be $370 million by 2010.
19. [Alternative Vehicles in Clean Cities] Figures show cumulative benefits from 1993 to 1998. Dollar savings are "current dollars."
20. [Ethanol Fuels Program] Figures show cumulative benefits through 1998 and are based upon the use of ethanol blends in gasoline beginning in 1982. Dollar savings are "current dollars."

**Emerging Technologies**

21. [High-efficiency refrigerators] Previous DOE investment saved $6 billion (in 1980 to 1990). This success story describes R&D accomplishments that could save an additional $6 billion per year. The DOE R&D investment is cumulative from 1991 through 1997.
22. [Combined heat and power] Investment is shown for FY1999. Annual energy savings, energy cost savings, CO2 emission reductions are calculated to be in effect by the year 2000.
23. [Lost foam metal casting] Investment from 1992 to 1997. Annual energy savings and energy cost savings occur if a 30% reduction in energy requirements of melting is achieved. There will also be a 700,000 ton reduction of solid waste.
24. [Nickel Aluminides] Energy displacement and cost savings as projected to be achieved by 2015. Investment is over the period 1982 to 1998 from DOE Offices of Science, Fossil Energy, and Energy Efficiency. There have been $3 million in sales of nickel aluminides through 1998.
25. [Photovoltaic thin film partnership program] DOE R&D investment is cumulative from 1994 to 1999. Energy savings, energy cost savings, and CO2 emission reductions are projections for the year 2020.
26. [Biomass gasifiers] DOE investment has been since 1994. Energy savings, energy cost savings and CO2 emission reductions are projections for the year 2010.
27. [High-temperature superconductivity equipment] Investment from 1996 to 1999. Energy cost savings are for the year 2010.

## APPENDIX B

## ACRONYMS AND GLOSSARY

### ACRONYMS

| | |
|---|---|
| AEO | Annual Energy Outlook |
| AER | Annual Energy Review |
| AFV | Alternative-fueled vehicle |
| ANL | Argonne National Laboratory |
| ASHRAE | American Society of Heating, Refrigeration, and Air-conditioning Engineers |
| BTS | Office of Building Technology, State and Community Programs |
| Btu | British Thermal Unit |
| CAFÉ | Corporate Average Fuel Economy standard |
| C | Carbon |
| CC | Combined Cycle |
| $CO_2$ | Carbon Dioxide |
| CRADA | Cooperative Research and Development Agreement |
| CT | Combustion Turbine |
| DOE | U.S. Department of Energy |
| EERE | Office of Energy Efficiency and Renewable Energy |
| EIA | Energy Information Administration |
| EPA | U.S. Environmental Protection Agency |
| EPACT | Energy Policy Act of 1992 |
| ESPC | Energy Savings Performance Contract |
| FEMP | Federal Energy Management Program |
| FY | Fiscal Year |
| GDI | Gasoline direct injection |
| GDP | Gross Domestic Product |
| GW | GigaWatt |
| HVAC | Heating, Ventilation, and Air-Conditioning |
| IGCC | Integrated Gasification Combined Cycle |
| kWh | kiloWatt-hour |
| LBNL | Lawrence Berkeley National Laboratory |
| LDV | Light-duty vehicle |
| MBtu | Million Btu |
| mmbd | million barrels of oil per day |
| MMTC | Million metric tons of carbon |
| MW | Megawatt |
| NAECA | National Appliance Energy Conservation Act of 1987 |
| NEMS | National Energy Modeling System |
| NREL | National Renewable Energy Laboratory |
| OIT | Office of Industrial Technologies |
| OPT | Office of Power Technologies |
| ORNL | Oak Ridge National Laboratory |
| OTT | Office of Transportation Technologies |
| PATH | Partnership for Advanced Technology in Housing |
| PM | Particulate matter |
| PNGV | Partnership for a New Generation of Vehicles |
| PNNL | Pacific Northwest National Laboratory |

| | |
|---|---|
| PV | Photovoltaics |
| R&D | Research and Development |
| RD&D | Research, Development and Demonstration |
| SEAB | Secretary's Energy Advisory Board |
| SNL | Sandia National Laboratories |
| tBtu | Trillion Btu |
| TWh | TeraWatt-hour |
| VMT | Vehicle miles traveled |
| VOC | Volatile organic compounds |

## GLOSSARY

**Barrel (petroleum):** A unit of volume equal to 42 U.S. gallons.

**Biomass:** Any organic matter available on a renewable or a recurrent basis, including agricultural crops and residues, wood and wood residues, urban and animal residues, and aquatic plants.

**Bioenergy:** Energy derived from biomass as electricity or heat, or combinations of heat and power; in the form of liquid or gaseous fuels, it is often referred to as biofuels.

**British thermal unit (Btu):** One British thermal unit, or Btu, is roughly equivalent to burning one kitchen match. It is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit. (one Btu = 1055 Joules)

**Carbon dioxide ($CO_2$):** A colorless, odorless, non-poisonous gas that is a normal part of the ambient air. Carbon dioxide is a product of fossil fuel combustion.

**Climate change:** The change in weather patterns and surface temperatures that appears to be occurring as the result of large increases in greenhouse gas concentrations in the earth's atmosphere.

**Cogeneration:** The production of electrical energy and another form of useful energy (such as heat or steam) through the sequential use of energy.

**Combined Cycle:** An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. Such designs increase the efficiency of the electric generating unit.

**Criteria Pollutant:** A pollutant determined to be hazardous to human health and regulated under the Environmental Protections Agency's (EPA) National Ambient Air Quality Standards. The 1970 amendments to the Clean Air Act require EPA to describe the health and welfare impacts of a pollutant as the "criteria" for inclusion in the regulatory regime.

**Crude oil:** A mixture of hydrocarbons that exists in the liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities. Crude oil production is measured at the wellhead and includes lease condensate.

**Discount Rate:** The interest rate used to assess the value of future cost and revenue streams; an essential factor in assessing true returns from an investment in energy efficiency, as well as opportunity costs associated with not making that investment. Real discount rates do not include inflation. To obtain the

equivalent nominal discount rate including inflation, simply add the percentage annual inflation rate to the real discount rate

**Distillate fuel oil:** The lighter fuel oils distilled off during the refining process. Included are products known as ASTM grades numbers 1 and 2 heating oils, diesel fuels, and number 4 fuel oil. The major uses of distillate fuel oils include heating, fuel for on- and off-highway diesel engines, and railroad diesel fuel.

**Electric Utility Restructuring:** With some notable exceptions, the electric power industry historically has been composed primarily of investor-owned utilities. These utilities have been predominantly vertically integrated monopolies (combining electricity generation, transmission, and distribution), whose prices have been regulated by State and Federal government agencies. Restructuring the industry entails the introduction of competition into at least the generation phase of electricity production, with a corresponding decrease in regulatory control. Restructuring may also modify or eliminate other traditional aspects of investor-owned utilities, including their exclusive franchise to serve a given geographical area, assured rates of return, and vertical integration of the production process.

**Energy:** The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatthours, while heat energy is usually measured in British thermal units.

**Energy Service Company (ESCo):** A company which designs, procures, finances, installs, maintains, and guarantees the performance of energy conservation measures in an owner's facility or facilities.

**Energy Saving Performance Contract (ESPC):** An agreement with a third party in which the overall performance of installed energy conservation measures is guaranteed by that party.

**Ethanol:** A denatured alcohol ($C_2H_5OH$) intended for motor gasoline blending.

**Externalities:** Benefits or costs, generated as a byproduct of an economic activity, that do not accrue to the parties involved in the activity.

**Fluorescent Lamps:** Fluorescent lamps produce light by passing electricity through a gas, causing it to glow. The gas produces ultraviolet light; a phosphor coating on the inside of the lamp absorbs the ultraviolet light and produces visible light. Fluorescent lamps produce much less heat than incandescent lamps and are more energy efficient.

**Fossil Fuel:** Any naturally occurring organic fuel formed in the Earth's crust, such as petroleum, coal, and natural gas.

**Fuel Cells:** One or more cells capable of generating an electrical current by converting the chemical energy of a fuel directly into electrical energy. Fuel cells differ from conventional electrical cells in that the active materials such as fuel and oxygen are not contained within the cell but are supplied from outside.

**Gas-Turbine Electric Power Plant:** A plant in which the prime mover is a gas turbine. A gas turbine typically consists of an axial-flow air compressor and one or more combustion chambers in which liquid or gaseous fuel is burned. The hot gases expand to drive the generator and then are used to run the compressor.

**Global Warming:** Global warming is the increase in global temperatures that the earth has been experiencing this century. Gases that are thought by many to contribute to global warming through the greenhouse effect include carbon dioxide, methane, nitrous oxides, chlorofluorocarbons (CFCs), and halocarbons (the replacements for CFCs). Carbon dioxide emissions are primarily caused by the use of fossil fuels for energy.

**Greenhouse Gas:** Any gas that absorbs infrared radiation in the atmosphere.

**Heat Pump:** A device that extracts available heat from one area (the heat source) and transfers it to another (the heat sink) to either heat or cool an interior space. Geothermal heat pumps can operate more efficiently than the standard air-source heat pumps, because during winter the ground does not get as cold as the outside air (and during the summer, it doe not heat up as much).

**Independent Power Producer (IPP):** A wholesale electricity producer (other than a qualifying facility under the Public Utility Regulatory Policies Act of 1978), that is unaffiliated with franchised utilities. Unlike traditional utilities, IPPs do not possess transmission facilities that are essential to their customers and do not sell power in any retail service territory where they have a franchise.

**Kerosene:** A petroleum distillate that is used in space heaters, cook stoves, and water heaters; it is suitable for use as an illuminant when burned in wick lamps (see Watthour).

**Kilowatt (kW):** One thousand watts of electricity (see Watt).

**Kilowatthour (kWh):** One thousand watthours.

**Light Truck:** Two-axle, four-tire trucks with a gross vehicle weight less than 10,000 pounds.

**Liquefied Natural Gas (LNG):** Natural gas (primarily methane) that has been liquefied by reducing its temperature to -260°F at atmospheric pressure.

**Liquefied Petroleum Gas (LPG):** Ethane, ethylene, propane, propylene, normal butane, butylene, and isobutane produced at refineries or natural gas processing plants.

**Low Emissivity (low-e) Coatings:** Emissivity is a measure of how much heat is emitted from an object by radiation. Low-e coatings are put on window panes to reduce the amount of heat they give off through radiation.

**Megawatt (MW):** One million watts of electricity (see Watt).

**Methanol:** A light volatile alcohol ($CH_3OH$) used for motor gasoline blending.

**Natural Gas:** A mixture of hydrocarbons (principally methane) and small quantities of various nonhydrocarbons existing in the gaseous phase or in solution with crude oil in underground reservoirs.

**Nitrogen Oxides ($NO_x$):** A product of combustion of fossil fuels whose production increases with the temperature of the process. It can become an air pollutant if concentrations are excessive.

**Nuclear Electric Power:** Electricity generated by an electric power plant whose turbines are driven by steam generated in a reactor by heat from the fissioning of nuclear fuel.

**Oxygenates:** Any substance which, when added to motor gasoline, increases the amount of oxygen in that motor gasoline blend.

**Ozone:** Three-atom oxygen compound ($0_3$) found in two layers of the Earth's atmosphere. One layer of beneficial ozone occurs at 7 to 18 miles above the surface and shields the Earth from ultraviolet light. Several holes in this protective layer have been documented by scientists. Ozone also concentrates at the surface as a result of reactions between byproducts of fossil fuel combustion and sunlight, having harmful health effects.

**Parabolic Trough:** A high-temperature (above 180 degrees Fahrenheit) solar thermal concentrator which focuses direct-beam solar radiation on a linear receiver along its focal line.

**Particulates:** Visible air pollutants consisting of particles appearing in smoke or mist.

**Petroleum:** A generic term applied to oil and oil products in all forms.

**Photovoltaic Cell:** An electronic device consisting of layers of semiconductor materials fabricated to convert incident light directly into electricity (direct current).

**Photovoltaic Module:** An integrated assembly of interconnected photovoltaic cells designed to deliver a selected level of working voltage and suited for incorporation in photovoltaic power systems.

**Primary Energy:** The energy that is embodied in resources as they exist in nature (e.g., coal, crude oil, natural gas, or sunlight). For the most part, primary energy is transformed into electricity or fuels such as gasoline or charcoal. These, in turn, are referred to as secondary or site energy.

**Propane:** A normally gaseous straight-chain hydrocarbon ($C_3H_8$). It is a colorless paraffinic gas that is extracted from natural gas or refinery gas streams.

**Quadrillion Btu (Quad):** Equivalent to 10 to the $15^{th}$ power Btu (1 quad = 1.055 x 10e18 joules).

**Renewable Energy:** Energy obtained from sources that are essentially inexhaustible (unlike, for example, the fossil fuels, of which there is a finite supply). Renewable sources of energy include conventional hydroelectric power, wood, waste, geothermal, wind, photovoltaic, and solar thermal energy.

**Standard Industrial Classification (SIC):** A set of codes developed by the Office of Management and Budget which categorizes industries according to groups with similar economic activities.

**Turbine:** A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two.

**Watt (Electric):** The electrical unit of power. The rate of energy transfer equivalent to one ampere of electric current flowing under a pressure of one volt at unity power factor.

**Watthour (Wh):** The electrical energy unit of measure equal to 1 watt of power supplied to, or taken from, an electric circuit steadily for one hour.

**Wind Energy:** The kinetic energy of wind converted into mechanical energy by wind turbines (i.e., blades rotating from a hub) that drive generators to produce electricity.



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