3.5 Residential and Commercial

Contents

Residential and Commercial

3.5.1 Technology Summary

Overview

DOE's Residential and Commercial program, within the Office of Energy Efficiency and Renewable Energy, undertakes activities to develop advanced natural gas technologies and promotes policies to increase economically efficient use of natural gas in commercial and residential buildings. The program supports cost-shared research, development, and commercialization of high-efficiency gas-fired heating, cooling, and major appliance technologies. Through partnerships with industry and stakeholders, the program aims at improving building sector energy performance, environmental quality and occupant productivity, and establishing U.S. leadership in a growing world marketplace for building equipment and appliances.

Department-Wide Program

In 1995, residential and commercial buildings in the U.S. used 32.7 quadrillion Btu of primary energy, 36 percent of U.S. total primary energy consumption. Residential buildings consumed 18.4 quadrillion Btu of energy in 1995, while commercial buildings used 14.3 quadrillion Btu. More than 32 percent of the energy used in the buildings sector was supplied by natural gas, either directly or through the generation of electricity, representing 48 percent of all natural gas consumed in the U.S. Space heating is the single largest end-use energy demand within buildings, accounting for 36 percent of residential building energy consumption and 15 percent of commercial building energy consumption. Space cooling and ventilation represents an additional 17 percent of commercial building energy use. The buildings sector is responsible for two-thirds of the Nation's electricity demand, with air conditioning the largest contributor to peak loads.

In addition to the $220 billion of direct costs that energy represents to consumers, building energy use contributes significantly to air and water pollution and depletion of the earth's non-renewable natural resources. Carbon dioxide emissions attributable to primary energy use in U.S. buildings constitute 35 percent of the U.S. and 9 percent of the global totals. In addition, energy use in buildings is responsible for 47 percent of U.S. sulfur dioxide emissions and 22 percent of nitrogen oxide emissions.

Dramatic improvements are being made in the efficiency of many aspects of energy use in the nation's buildings. However, these improvements are being overpowered by strong sectoral growth and increased demand for energy services, which have led to significant increases in overall energy demand, with concomitant cost increases to consumers and damage to the environment. There are currently more than 76 million residential buildings and 4.8 million commercial buildings in the U.S., which together contain over 250 billion square feet of floorspace, and 38 million new residential and commercial buildings will be constructed between now and 2010. The number of households has grown by 25 percent since 1980, while residential primary energy demand has increased by 22 percent. Over the same period, commercial floorspace has increased by 39 percent, accompanied by primary energy demand growth of 35 percent. Use of energy consuming equipment and appliances is increasing dramatically at home and work. Further, demand growth is expected to continue. The Energy Information Administration projects an increase of 4.0 quads by 2010, a 12 percent increase. This increase would require investment in an additional 30 gigawatts of electricity generating capacity, costing approximately $20 billion in capital that could be applied to other more productive and employment-intensive investments.

The Office of Building Technology, State and Community Programs (BTS) provides technology leadership to make U.S. buildings more efficient, comfortable, affordable, and sustainable. The goal of BTS is to limit non-renewable energy use in buildings through cost-effective improvements in energy efficiency and expanded use of renewable energy. This will be accomplished by developing new, cost-effective, environmentally-benign technologies and stimulating use of the best new and currently available technologies. An integrated, three-component strategy is used to bring about the required improvements: (1) research, development, and demonstration and practical application of advanced energy-efficient and renewable energy technologies; (2) appliance and building codes and standards; and (3) market outreach and conditioning. The Administration, through the National Science and Technology Council, has designated the buildings and construction industry as one of nine priority areas for federally assisted research.

Program Activity Summary

The Residential and Commercial program focuses on cost-shared research and development of advanced technology for heating, cooling, and ventilating buildings and partnerships with industry to accelerate the introduction of new technology. It seeks to: (1) support development of cost-effective advanced natural gas technologies for space conditioning and water heating; (2) promote and accelerate natural gas technologies to meet the provisions for air quality goals; (3) support deployment and integration of advanced utilization technologies, including cogeneration systems using fuel cells in the buildings sector; and (4) advance the state-of-the-art in computing and information technologies to assist in full integration of natural gas systems.

The program goals are to reduce energy use in space heating and cooling by 50 percent, when the program's advanced technology has fully penetrated the market, and to eliminate ozone-depleting refrigerants while increasing energy efficiency, all while improving comfort and productivity of buildings and reducing emissions. Within residential buildings, advanced gas-fired heat pump technologies now being developed have the potential to double the efficiency of conventional equipment used for space heating and cooling, and for water heating. Advanced chillers and small-scale fuel cells are two technologies under development that will improve commercial building energy performance while dispatching electricity with natural gas during the Summer peak demand periods. Advanced desiccant technology will allow increased ventilation for improved air quality, as required by ASHRAE standards, while also reducing energy consumption.

Partners in the Department's efforts to address natural gas-fired building equipment include small business R&D firms, manufacturers, utilities, and professional organizations. The DOE program is coordinated with R&D activities of the Gas Research Institute (GRI), the American Gas Association (AGA), and the Electric Power Research Institute (EPRI). GRI has a multimillion dollar research program that is focusing on building equipment and appliance energy performance and is closely coordinated with DOE. Similarly, AGA supports advanced natural gas cooling and dehumidification technology R&D. DOE, the natural gas industry, and EPRI are conducting research on fuel cells for building applications.

Lower operating costs, compared to competing fuels, and expanded distribution systems contribute to the competitiveness of natural gas for space heating and water heating applications. However, the higher first-costs that are typical for natural gas-fired cooling technologies and appliances compared to competing equipment often act as a purchase barrier, particularly in new construction markets.

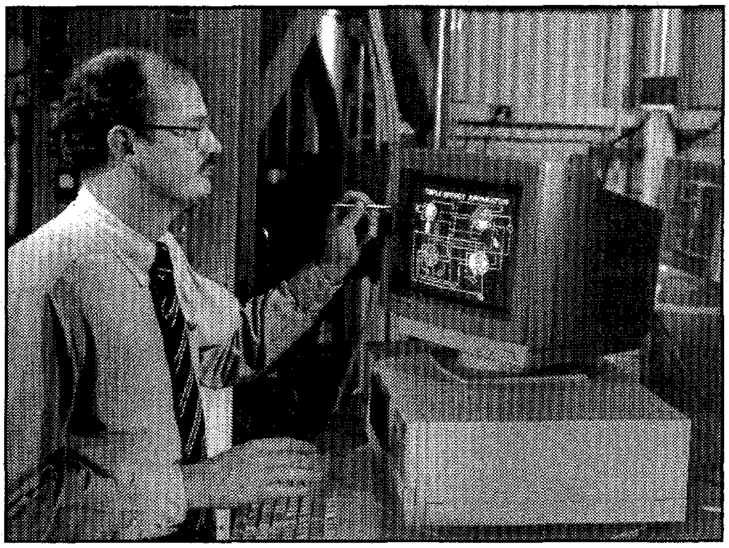
Section 127 of the Energy Policy Act of 1992 (EPACT) specifically directs DOE to assess the potential for development and commercialization of natural gas-driven building appliances, including heating and cooling equipment, that are substantially more efficient than those required by Federal or State laws, and to recommend specific actions that DOE could take in assisting utilities and appliance manufacturers in product development and commercialization. In implementing the requirements of EPACT Section 127, a significant part of DOE's program will target technical and market obstacles that impede adoption of advanced building equipment and appliance technologies. Joint DOE/industry participation in efforts to develop and deploy high performance natural gas-driven products is a critical element in fostering use of natural gas within the buildings sector.

Program Schedule (1995-2002)

FY 1995

- Initiated two contracts to evaluate new and emerging desiccant technologies with teams consisting of a desiccant manufacturer and an heating, ventilation, and air conditioning (HVAC) system manufacturer.
- Completed a marketing study on fuel cell cogeneration in buildings and conducted two industry workshops to guide program planning.

Oak Ridge Researcher Uses a Computerized Simulation Tool to Analyze an Advanced Absorption Chiller



FY 1996

- Completed a preliminary assessment of the application of the Generator Absorber Heat Exchanger (GAX) absorption technology in small commercial buildings.
- Awarded four Small Business Innovation Research (SBIR) contracts to conduct research on critical technical problems related to development of PEM fuel cell applications in buildings.

FY 1997

- Initiation of fabrication of a full production model of a 400-ton natural gas Double Condenser Coupling absorption chiller using DOE's advanced Double Condenser Coupling (DCC) technology at York International.
- Award of three cost-shared contracts for the development of fuel cells for buildings.
- Transfer of the Absorption Simulation (ABSIM) computer design model for absorption heat pumps to industry.

FY 1998

- Completion of R&D on two new natural gas absorption heating/ cooling products with 40 percent higher efficiency than existing technologies.
- Completion of a study of liquid desiccant systems and development of an R&D plan.

FY 1999

- Initiation of testing a laboratory prototype version of a natural gas heat pump using advanced absorption technology.
- Market introduction of an advanced DCC chiller for large commercial applications.
- Finalize analysis of "Figure of Merit" for desiccant wheel configurations, designs, and materials and publication of results for use by system designers.

FY 2000

- Market introduction of the GAX absorption heat pump for residential applications.
- Development and introduction of design tools for desiccant system development and applications studies.

FY 2001

- Market introduction of a desiccant-based ventilation-air preconditioner integrated into a modular HVAC system.

FY 2002

- Completion of "first-generation" prototype 50 kW PEM fuel cell for buildings.

FY 1996-1998 Crosscut Budget Summary ($ in Millions)

Programs	FY 1996	FY 1997	FY 1998
Thermally Activated Heat Pumps	6.0	6.4	5.5
Advanced Desiccant Technology	0.0	1.5	2.1
Fuel Cells for Buildings	0.0	1.0	1.0
Total	**6.0**	**8.9**	**8.6**

3.5.2 Project Descriptions

3.5.2.1 Thermally Activated Heat Pumps

Background

Heating, ventilation, air conditioning, and refrigeration equipment in U.S. residential and commercial buildings use 15 quads of primary energy, or nearly half of all building energy consumption. Air conditioning is also the single leading cause of electric system peak loads. Energy use in buildings also has serious environmental impacts, contributing one-third of U.S. greenhouse gas emissions. Refrigerant fluids used in building air conditioning systems are major contributors to stratospheric ozone depletion.

The Thermally Activated Heat Pump (TAHP) can revolutionize the way buildings are heated and cooled. Using natural gas as the fuel of choice, it offers an efficient alternative to space conditioning in both residential and commercial buildings. It enables highly efficient heat pump cycles to replace the best natural gas furnaces, reducing energy use by as much as 50 percent, while also providing gas-fired air conditioning. In large commercial-size absorption chillers, energy efficiency can be improved by 50 percent with advanced high-temperature cycles and novel fluids. The principal thrust of the program is system development and deployment, field testing, and commercialization of systems.

Major Goals

The project will develop and introduce to the market new gas-fired heat pumps and chillers for use in residential and commercial buildings that are 50 percent more energy efficient than the best technology presently available; specifically:

- An advanced commercial-size (DCC) LiBr/H_2O absorption chiller in 1999.
- A residential-size absorption heat pump for use primarily in northern climates in 2000.
- A second-generation residential-size absorption heat pump with improved cooling performance for use in southern climates in 2005.

Project Objectives

The objective of this project is to develop and commercialize a new generation of advanced absorption cycle heat pumps and chillers for residential and commercial space conditioning operating on natural gas.

Expected Benefits

Gas-fired absorption heat pumps and chillers are adaptable nationwide in both new and retrofit applications in residential and commercial buildings. With full market penetration, this technology can reduce primary energy use for space heating, space cooling and water heating by 4 quads by the year 2020, while also reducing substantially the electric load peaking problem experienced by electric utilities during summer cooling. It will reduce emissions of CO_2 and other environmental pollutants from heating and cooling systems by over 60 percent, without using ozone-depleting CFC and HCFC refrigerants. It will also increase international competitiveness of U.S. industry through globally marketable technology and products.

Planned Products

This project will lead to the introduction of three specific hardware systems for space conditioning of buildings: an absorption heat pump for use primarily in heating of residential and small commercial buildings, a second-generation, "Hi-Cool" heat pump with improved cooling performance, and a LiBr/H_2O absorption chiller for use in large commercial buildings. In the course of this work, it will also produce improvements in system components, including materials and fluids. A computerized design tool for absorption systems will be made available for use by industry.

Strategy (FY 97 Funding: $6.4 Million)

Thermally activated heat pumps can achieve significant penetration in all three distinct heating, ventilation, and air-conditioning markets: residential, small commercial, and large commercial. Since the residential market has the greatest potential for energy savings, it is the primary emphasis of the program. Large commercial technology is pursued in parallel, as funding allows. The small commercial market will be addressed in the future by building on the residential technology base.

For the residential market, the strategy is to develop two levels of technology sequentially . The "first generation" technology is the Phillips Engineering Company's Generator Absorber Heat Exchanger (GAX) absorption cycle, or the equivalent. The primary market will be in the northern half of the country, due to the good heating performance of the GAX system. The main thrust of the TAHP program is on the residential GAX effort.

The second-generation, "Hi-Cool" residential absorption heat pump technology will expand the residential market to include the southern cooling-dominated region. The improved level of cooling performance can only be achieved with major new advancements in absorption technology or with an engine-driven system. The program strategy is to pursue technology screening efforts at a high level, in parallel with the first generation GAX effort, to determine the most attractive "Hi-Cool" technology. The program's primary focus is to take advantage of new technologies and share new developments between the programs to bring the latest tools to a marketable state.

The technology of large commercial chillers is quite different from that of residential heat pumps and requires separate development efforts. The program is continuing to work with a major U.S. manufacturer in the development, testing, and commercialization of an advanced Double Condenser Coupled (DCC) commercial $LiBr/H_2O$ chiller, which is expected to be 50 percent more efficient than the Japanese-designed chillers now being built and sold in the United States. This DOE-patented DCC technology is being pursued at a rapid pace consistent with its potential for near-term commercialization.

Supporting research is carried out in key technical areas to enable current concept developments to proceed and to form the basis for future advanced concepts with even higher energy saving potential. The work is carried out through industry cost-shared programs with major manufacturers and small business establishments, R&D firms, universities and national laboratories, in close coordination with the Gas Research Institute (GRI) and major gas utilities.

Major activities underway in FY 97 are:

- Phillips Engineering Company is completing the design optimization of the GAX absorption heat pump, which uses NH_3/H_2O as the working fluid, and will begin testing a complete prototype heat pump at Oak Ridge National Laboratory (ORNL). The target Coefficient of Performance for heating (COPh) is 1.6 and the Coefficient of Performance for cooling (COPc) is 0.7. The R&D program is funded by DOE and cost-shared by the Gas Industry Consortium, made up of the Gas Research Institute and several major gas utilities. In May 1997, a U.S. manufacturer of gas-fired air conditioners announced that it is preparing to market a GAX chiller in 1998, as a prelude to its development of a GAX heat pump.
- A major HVAC equipment manufacturer is beginning tests on a prototype 400-ton DCC $LiBr/H_20$ chiller for COPc of 1.4 or better. The major development focuses on materials of construction, absorption fluids additives for heat and

mass transfer, and corrosion abatement at high- temperature operation of the lithium bromide/water system.

- Two contractors have been selected and are beginning to develop advanced concepts for a second-generation, "Hi-Cool" residential absorption heat pump. This advanced heat pump will have a 30 percent improvement in cooling performance, based on previous development of absorption concepts.
- Development and transfer to industry will continue on the Absorption Simulation (ABSIM) computer program. There is no publicly available computer model for the design or analysis of absorption cycles using NH_3/H_2O. The introduction of ABSIM will provide a "first-generation" computer model for the design engineer and research specialist comparable to computer models used in electric heat pump design.

Recent Accomplishments

- Completed a comprehensive design and cost analysis of the GAX heat pump.
- Completed a comprehensive market study for the commercial GAX heat pump.
- Completed a preliminary study of the design, layout, and cost of a manufacturing plant for the production of the GAX heat pump.
- Completed design and began fabrication of a prototype DCC large commercial chiller with York International.
- Studies at the University of Maryland and Pennsylvania State University were completed, with several potential high-temperature refrigerant additives identified. This information is being shared with HVAC equipment manufacturers.

Schedule

- Develop and commercialize the GAX absorption heat pump for residential applications by 2000, and for small commercial applications by 2003, in collaboration with Phillips Engineering Company, the gas industry, and equipment manufacturers.
- In collaboration with industry, introduce to the market an advanced DCC absorption $LiBr/H_20$ chiller for large commercial applications. (1999)
- Complete component development and begin system development by 2002 for the second-generation "Hi-Cool" heat pump, as a step leading to introduction of a residential-size absorption heat pump. (2005)

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Residential Absorption Heat Pump	3.7	4.2	4.3
"Hi-Cool" Heat Pump	1.1	0.9	0.9
Computer-Aided Design	0.2	0.2	0.0
Large Commercial Chiller	1.0	1.1	0.3
Total	**6.0**	**6.4**	**5.5**

Cost Sharing (Percentage / $ in Millions)

	FY 1996	FY 1997	FY 1998 Estimate
Percentage	33	33	35
Total ($)	**2.0**	**2.1**	**1.9**

3.5.2.2 Advanced Desiccant Technology

Background

Conventional vapor-compression refrigeration cooling systems cannot effectively handle high humidity loads. This leads to installation of oversized compressors for dehumidifying incoming air and then reheating dry air to achieve some level of comfort, an approach which is costly but often still inadequate. Desiccant systems can supplement the performance of conventional air conditioners by working together to meet the temperature and humidity loads of the building. Compressor size can be reduced and excess chiller capacity can be eliminated, resulting in reduced energy consumption but improved air quality and occupant comfort.

However, to be acceptable in the market, desiccant-based air conditioning systems have to overcome several problems:

- *Cost*: Desiccant systems are commonly perceived as an expensive, inefficient space conditioning technology. Although advancements in desiccant material and equipment design have improved performance and reliability and reduced the cost of desiccant equipment, further cost reductions and technical improvements are needed to allow these systems to compete successfully in the broader commercial and residential building markets.
- *Information*: Capacity and operating efficiencies for desiccant and vapor compression equipment are not expressed in equivalent terms. To permit product comparison and specification, a set of standardized test procedures and certification criteria are needed for desiccant-based systems, along with design tools to allow evaluation and optimal configuration of equipment. Conventional comfort standards, based primarily on temperature, must be revised to incorporate responses caused by humidity and indoor air quality.
- *Physical Size*: The relative size of equipment using desiccant components is larger than comparable vapor compression systems. Size reduction would make desiccant technologies more acceptable and cost-effective for mainstream HVAC equipment markets.

This project works with industry to identify and remove barriers and expand the technology into broader space-conditioning markets, where its full energy savings potential and contribution to improved indoor air quality can be realized. An industry-led program is critical to the success of the technology. In response, DOE is collaborating with the U.S. Air Quality (USAQ) Consortium and gas industry to accelerate this process.

Major Goals

The project will assist industry in developing and commercializing desiccant technology to be integrated into 10 percent of the air conditioning market by 2005 and 25 percent by 2010, allowing buildings to achieve indoor air quality improvements resulting from increased ventilation requirements, without any corresponding increase in energy consumption.

Project Objectives

The objective of the gas-fired desiccant cooling program is to bring manufacturers of desiccant systems together with manufacturers of HVAC systems to accelerate the incorporation and commercialization of improved desiccant technology into broader markets for comfort conditioning in commercial and residential buildings, leading to the introduction of new, marketable desiccant products under recognizable HVAC brand names. The project will provide information and procedures to facilitate the design and selection of desiccant systems by HVAC engineers. It will also assist in training of end-users and market promotion of desiccant-based HVAC equipment.

Expected Benefits

Desiccant systems can decouple latent and sensible heat loads in building space conditioning systems and improve quality of ventilation air. Desiccants offer many advantages over conventional HVAC cooling systems, including: improved indoor air quality (IAQ), reduced energy bills, reduced peak demand on summer peaking electric utilities, load-shifting of natural gas use in summer months, utilization of waste heat, reduced use of ozone-depleting chemicals, reduced emissions of global-warming gases, more comfortable working/living conditions, and reduced remodeling requirements.

The unique advantages of desiccant-based equipment over conventionally used vapor-compression air conditioning systems can be shown for any building where significant amounts of replacement air is required. Desiccant technology is successfully being used in various niche markets throughout the U.S. where it can solve several problems that cannot be handled by conventional systems alone. Applications include:

- *Supermarkets*, by reducing frost build-up on refrigerated cases and frozen food products, thereby extending product shelf life and extending the interval between energy-consuming defrost cycles.
- *Hotels and dormitories*, where large volumes of outdoor air are needed to make up for bathroom exhaust air, and where frequent showers and baths generate humidity too high for the conventional room air conditioner to handle, causing moisture damage to carpeting, draperies, and furnishings.
- *Nursing homes and hospitals*, which need large quantities of outdoor air for health and odor maintenance, humidity control in operating rooms for antiseptic reasons, and maintenance of relative humidity levels below 50-60 percent relative humidity for comfort of staff and patients.
- *Large retail stores and shopping malls*, where it is critical to maintain customer comfort over a wide range of occupancy levels.

The commercial market will be driven by requirements of the new ASHRAE Standard 62-89R, Ventilation for Acceptable Indoor Air Quality, which calls for increased use of outside "fresh air" for ventilation, improved air quality, and healthier conditioned spaces. Desiccants will allow the increased ventilation requirements to be met without any corresponding increase in energy consumption.

Specific benefits expected from this project are:

- Reduction in energy consumption by 0.1 quads annually by 2005 and 0.4 quadrillion Btus annually by 2010; and
- Reduction in carbon dioxide emissions by 6 million tons annually by 2005 and 24 million tons annually by 2010.

Planned Products

This project will develop and commercialize hybrid desiccant-based cooling systems for improvement of indoor air quality without any corresponding increase in energy consumption. It will also provide the following information, which will facilitate the incorporation of desiccant technology into HVAC system design:

- Development and implementation of standard test and performance ratings and product certification procedures for desiccant systems, using test conditions that are indicative of real-world field operations;
- Development of a "figure of merit" for desiccant wheel comparison;
- Development of design tools for integrated desiccant-based systems;
- Development of a data base for the comparison of hybrid desiccant/HVAC equipment with vapor compression cooling equipment.

Strategy (FY 97 Funding: $1.5 Million)

Initial emphasis will be on development of solid desiccant for integrated roof-top commercial markets such as schools, hospitals, hotels and office buildings where moisture control, ventilation and indoor air quality are major problems but first costs becomes less of an issue. Desiccant systems will be designed that can treat humidity and latent heat prior to sensible cooling, thereby significantly reducing the need for larger tonnage air conditioners. Reduced latent load allows for a reduction in duct sizing, air handling equipment, and chiller capacity, resulting in significantly lower capital investment and operating cost. Desiccants will be needed for rigorous code compliance if the prescriptive provisions of ASHRAE 62-89R are adopted.

Feasibility studies will be conducted on liquid desiccant systems to determine the major impact they will have in applications for HVAC and IAQ markets.

ASHRAE Standard 62-1989R requires supplying more ventilation air than the previous standard in most commercial buildings. Minimum ventilation rates are required to provide IAQ acceptable to human occupants and avoid adverse health effects. ASHRAE Standard 90.1 has reduced building envelope loads, with improved thermal insulation and high-efficiency lighting equipment placing more emphasis on latent rather than sensible heat loads. However, conventional air conditioners were not designed to handle increased ventilation rates or latent loads, and cannot comply with the required standard without dramatically increasing energy consumption.

Desiccant systems can effectively and efficiently reduce the latent-load component for existing buildings to offset potential reduced capacity from refrigerant conversions or the need to provide increased electric service to maintain cooling capacity. Because of design changes required by ASHRAE 62-89R and 90.1, new desiccant system design must be benchmarked against conventional systems that meet the requirements of the ASHRAE standards.

There are significant technical issues that must be resolved before desiccant systems can be successfully integrated into broad building space conditioning markets, such as:

- A need for "hard" data on overall system cost and performance tradeoffs
- A need for broad performance maps for desiccant wheels and materials
- A need to develop experience in controlling both temperature and humidity in buildings
- Material science for integration of desiccant systems with the HVAC heat exchanger for temperature matching
- Analytical modeling capability for understanding system heat and mass transfer
- Computer models for system integration and operation

Project work in FY 97 will help to address these issues. Specifically:

- Field evaluation of an advanced desiccant system developed by an industry team will provide side-by-side performance comparisons with conventional equipment and determine the data required for future product improvements and re-engineering. Six test sites have been selected. Using testing and rating procedures prepared by the manufacturer, ORNL and National Renewable Energy Laboratory (NREL) technical staff will monitor the field testing.
- Testing is underway on a desiccant-based air pre-conditioner developed by an industry team to determine and analyze applications that would best benefit from this design approach. The system separates outdoor-air latent

loads from sensible loads that can be conveniently handled by conventional vapor-compression cooling equipment.

- NREL is testing desiccant wheel cartridges donated by five desiccant wheel manufacturers. The test program will characterize various existing dehumidifiers and use the date to establish a baseline performance date base for existing technologies. The baseline performance data will provide technical support for the drafting of realistic performance test methods and for field monitoring of advanced components in collaboration with desiccant equipment manufacturers.
- Algorithms from NREL's and ORNL's testing programs are being provided to manufacturers and software developers for inclusion in the design software.
- NREL, in conjunction with a major manufacturer, initiated a study of liquid desiccant dehumidifiers.

Recent Accomplishments

In a joint effort with industry, DOE initiated contracts to evaluate new and emerging desiccant technologies by two teams, each consisting of a desiccant manufacturer and an HVAC system manufacturer.

NREL has established a facility for testing desiccant wheels under a wide range of realistic operating conditions.

Schedule

- Complete technical support for development of industry-wide test procedures and rating and certification methods in conjunction with ASHRAE and the Air Conditioning and Refrigeration Institute. (1998)
- Complete study of liquid desiccant systems and develop an R&D plan. (1998)
- Finalize analysis of "Figure of Merit" for desiccant wheel configurations, designs, and materials and publish results for use by system designers. (1999)
- Complete design tools for product development and applications. (2000)
- Introduce to the market a desiccant-based ventilation-air preconditioner integrated into a modular HVAC system. (2001)
- Develop and commercialize inexpensive sensors and equipment controls that optimally combine temperature level measurements with humidity and IAQ assessment, to fully exploit the potential for new indoor comfort standards and energy saving potential of desiccant-based air conditioning equipment. (2001)
- Develop a liquid desiccant system for integration with HVAC applications. (2002)

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Advanced Components and Applications	0.0	0.5	0.9
System Development Demonstration	0.0	1.0	1.2
Total	**0.0**	**1.5**	**2.1**

Cost Sharing (Percentage / $ in Millions)

	FY 1996	FY 1997	FY 1998 Estimate
Percentage	--	40	38
Total ($)	**0**	**0.6**	**0.8**

3.5.2.3 Fuel Cells for Buildings

Background

On-site uses of natural gas in residential and commercial buildings, for such functions as space heating and water heating, are directly responsible for 37 percent of U.S. natural gas consumption. However, the buildings sector also consumes about two-thirds of all electricity generated in the U.S., for servicing a wide range of space-conditioning and appliances loads. Generating this electricity for buildings consumes an additional 11 percent of U.S. natural gas consumption. On a primary energy basis, the buildings sector accounts for 36 percent of total U.S. energy consumption from all sources. Consequently, the large direct and indirect fossil fuel requirement to provide anticipated building energy needs is the driving force behind DOE's efforts to develop high-efficiency end-use equipment as part of its technology development strategy. High-efficiency building cogeneration systems using fuel cells is a key technology option for improving building energy efficiency.

DOE recognizes that successful development and commercialization of fuel cell cogeneration systems in buildings will require support and commitment of both manufacturers and potential end-users. To this end, the initial focus will be on developing the proton exchange membrane fuel cell (PEMFC) by addressing key technologies unique to building applications, and by using the large technology base being developed for transportation and military programs. Successful development of fuel cell technologies for buildings will dramatically reduce primary energy consumption in buildings and will significantly reduce electric/gas utility infrastructure needs, with associated cost savings.

It is important to note that the Fuel Cell for Buildings program will provide strategic support for the transportation fuel cell program by focusing on those near-term technologies that are common and synergistic to the automotive program. The buildings program will provide an accelerated commercialization path for the PEMFC and a near-term market for the technologies. In large part, cost reduction of fuel cell components in the buildings program will lead to reduced cost for components in the automotive program. The availability of near-term, multiple markets for the technologies greatly reduces the business risks associated with the development, thereby enhancing the level of industry commitments and participation in transportation, military, and stationary power applications.

Major Goals

This program will develop and demonstrate a "first-generation" prototype PEMFC for buildings in 2002, leading to market introduction by 2004. In addition, the technology base will have been laid for a second-generation system with lower cost, longer life, and greater adaptability to cogeneration use in buildings.

Project Objectives

The objective of the Fuel Cells for Buildings program is to develop key technologies for PEMFCs that are unique to building applications, cost-effective, and efficient, and that will provide a coupling between the fuel cell and the building suitable for cogeneration, supplying both the electric and thermal load requirements of the buildings. Where possible, this program will adapt technologies being developed for the PEMFC in transportation and military programs that are applicable to use in buildings.

Expected Benefits

The widespread use of fuel cell waste heat for cogeneration in buildings will reduce consumption of primary fuels by the building sector by a factor of two over current practices. Additional national benefits include:

- Significant reductions in CO_2 emissions as the result of the large reduction in primary energy use.

- Positioning United States industry as leaders in this dynamic technology area (as evidenced by the attention being given to its development in Japan and Europe) with associated implications for worldwide sales and domestic job creation.
- Reduction in the need for electric utility infrastructure (generating, transmission and distribution) with associated cost reductions in the delivery of electric services.

The impact of cogeneration system waste heat is an important consideration in evaluating system economics. Besides cogeneration, fuel cells will provide additional opportunities, including the use of distributed fuel reforming and direct-current (DC) appliances to further enhance cost-effectiveness and energy savings of system economics.

Planned Products

This work will produce a "first-generation" prototype 50-kW PEMFC installation by 2002, followed by a commercial product by 2004. Development study will begin in 1999 on an advanced, second-generation system.

Strategy (FY 97 Funding: $1.0 Million)

The program will focus initially on commercial buildings, due to a combination of their more favorable load characteristics, particularly high electric rate structures, the economies of scale associated with equipment implementation (particularly controls and fuel processing), and consistency with the capacity range being developed for transportation applications (50 to 300 kW). Successful development of the technology for commercial applications will provide a basis for addressing the large market potential in residential buildings.

The commercial building sector consists of over 4.5 million buildings, of which almost 4.2 million are occupied. Servicing the electric and thermal needs of these buildings accounts for more than 13 quads of primary energy consumption. Office, health, lodging, mercantile and education collectively account for over 50 percent of the total energy consumption in this sector. Of equal importance for assessing cogeneration potential is the typical energy use per building. On this basis, the most energy intensive buildings are used for *health care, lodging and education,* in that order.

The design and evaluation of cogeneration systems must take into account the daily and seasonal variations in both electric and thermal loads. Of particular importance for system design and economics is the coincidence of electric and thermal loads, since production of these two energy forms are simultaneous within a cogeneration unit. Two of the most important design strategies for cogeneration are:

- *Thermal-to-Electric (T/E) Ratio*: A measure of the ratio of the annual thermal loads of the building to its annual electric loads. A low T/E ratio implies relatively little use for reject heat developed by the cogeneration systems in space/water heating functions.
- *Electric Capacity Factor*: The ratio of the kWh used annually in the building to that which would be used if the building operated 100 percent of the time at peak load. A high capacity factor implies a relatively steady electric load, and a low capacity factor implies a highly variable electric loads. The annual T/E ratio for the selected buildings ranges from about 0.1 for office buildings (i.e., little use of waste heat) to over 0.5 for high usage buildings. As would be expected, the T/E ratios are considerably higher in a northern climate than in the south, due to space heating requirements in the north. The highly seasonal nature of such loads is, however, a significant challenge in system design.

The Fuel Cell for Buildings program began in FY 97, based on groundwork laid by program-planning workshops and a market study. The advances made in the Automotive Fuel Cell program and buildings-related projects funded through the Small Business Innovations Research (SBIR) Program will provide information for the development of a near-term "First Generation" fuel cell appropriate for building applications. Initial focus will be on selective research and component modification for building applications to include:

- Steam reforming of methane for PEMFC, which is not being done by other programs.
- Carbon monoxide clean-up, which is critical to mitigating catalyst poisoning problems.
- Cost reduction engineering to bring fuel cell cost near $1,500-2,000/kW.
- Heat exchanger development for efficient use of waste heat for cogeneration.
- Improved bearing and seals for air compressors and expander to reduce parasitic power.

The FY 97, Program Research and Development Announcement for Integrated Fuel Cell Systems and Components for Transportation and Buildings resulted in the award of three cost-shared contracts with industry for development of fuel cells for cogeneration in buildings.

Recent Accomplishments

Two "Fuel Cell/Integration for Buildings Program" workshops were held to identify applications, technical problems, and policy issues, with attendance by more than 50 specialists from industry, universities, and government.

Arthur D. Little, Inc., produced an extensive "Cost/Performance Requirements and Markets" study that provided further program planning guidance.

In FY 96, four Phase I contracts were awarded through the SBIR program to do research in four separate technologies, as follows:

- Novel proton exchange membrane materials to reduce crossover of methanol into the hydrogen fuel stream.
- Natural gas reformer clean-up system for the PEM fuel cell, to remove CO from the fuel stream.
- Development of anodes that are CO tolerant, to mitigate the problem of catalyst poisoning.
- Develop low-cost bi-polar plates for PEMFC.

The results of this research will be incorporated into the development of a 50-kW laboratory test PEMFC.

Schedule

Successful completion of the "first-generation" PEM fuel cell activity will provide:

- A complete methane steam reformer for testing in a breadboard 50-kW PEMFC (1999).
- A complete laboratory engineering prototype 50-kW PEMFC for system-level testing (2000).
- First-generation prototype 50-kW PEMFC for buildings (2002).

This schedule will lead to a commercial product based on the "first-generation" PEMFC by the year 2004. It will also provide substantial technical, business, and market acceptance of the 50-kW PEMFC in support of the transportation application which will be working in parallel to solve those problems unique to the automotive application. Cost reduction engineering in both programs will greatly help reduce cost structure and further accelerate marketability of the PEMFC.

In FY 99, work will begin on an advanced, "second-generation" PEMFC that will greatly extend the useful life, will operate at atmospheric pressure, have a significantly lower cost per kW and be more adaptable to building applications. Advances that will be made to the PEMFC will give the "second-generation" PEMFC the following characteristics:

- Useful operating life in excess of 40,000 hours.
- Advanced reforming techniques for natural gas, i.e., partial oxidation (POX).
- Membranes that will operate at higher temperatures for better, more diverse cogeneration applications.
- Packaging modifications for reduced size and weight.
- Reduction of the "market clearing price" for the PEMFC to $1,000-1,500/kW.
- Operation at atmospheric pressure.
- Improved anode/catalyst loading.
- Maximum heat transfer capability.

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Fuel Cells for Buildings	0	1.0	1.0
Total	**0**	**1.0**	**1.0**

Cost Sharing (Percentage / $ in Millions)

	FY 1996	FY 1997	FY 1998 Estimate
Percentage	--	40	40
Total ($)	**0**	**0.4**	**0.4**