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Federal Technology Alert

A publication series designed to speed the adoption of energy-efficient and renewable technologies in the Federal sector

Transpired Collectors (Solar Preheaters for Outdoor Ventilation Air)

Simple, reliable technology can substantially reduce heating bills.

The President's Million Solar Roofs Initiative aims to install 1 million solar energy systems on residential, commercial, and public-sector buildings by 2010. Twenty thousand of those systems will be installed on Federal buildings. In support of the Initiative, and as part of a continual effort to ensure U.S. buildings are energy efficient and environmentally sustainable, the U.S. Department of Energy's Federal Energy Management Program (FEMP) will help install those solar systems targeted for the Federal sector.

FEMP is focusing on solar systems that include photovoltaics (PV), solar hot water for buildings and swimming pools, and solar space heating. Transpired solar collectors are a solar space-heating technology that is well proven, is readily available, and has considerable potential for application at Federal facilities. Transpired collectors use solar energy to preheat ventilation (outdoor) air as it is drawn into a building. The technology is ideally suited to building applications in which large volumes of space are heated or where high ventilation rates are required. By preheating ventilation air with solar energy, the technology removes a substantial load from a building's conventional heating system, saving energy and money. This *Federal Technology Alert* (FTA) is designed to give Federal facility managers the information they need to decide whether transpired collector technology is suitable for their facility.

Energy-Saving Mechanism

A transpired collector reduces the load on a building's heating system by heating intake air with solar energy. It preheats the ambient air by up to 40°F, reducing all or a portion of the load on a heating system during daylight hours. Although the transpired collector may not be able to achieve the required indoor air temperature on cloudy days or when the outside temperature plummets, it provides useful energy and reduces utility bills.

In addition to meeting a portion of a building's heating load with clean, free solar energy, the transpired collector helps

Keith Gawlik, NRE/PIX04118

save energy and money in other ways. It recaptures heat loss through a building's south-facing wall; heat that escapes through the south wall is captured in the air space between the structural wall and the transpired collector and returned to the interior. Also, by introducing make-up air through ceiling-mounted ducts, the system eliminates the wasteful air stratification that often plagues high-ceiling buildings.

Technology Selection

The FTA series targets technologies that appear to have significant untapped Federal-sector potential and for which some Federal installation experience exists. The new technologies presented in the series were identified through trade journals and through direct correspondence. Numerous responses were obtained from manufacturers, utilities, trade associations, research institutes, Federal sites, and other interested parties. Based on these responses, the technologies were evaluated in terms of potential Federal-sector energy savings and procurement, installation, and maintenance costs. They were also categorized as either just coming to market ("unproven" technologies) or as technologies for which field data and experience exist.

Transpired collectors are one of many energy-saving technologies to emerge in the last 20 years. They were judged to be life-cycle cost effective (at one or more Federal sites) in terms of installation cost, net present value, and energy savings. Several other proven technologies have been slated for further study through the *Federal Technology Alert* series.

Application

Any heated building in a cool, sunny climate that has at least moderate ventilation requirements and southern exposure could benefit from a transpired collector. Buildings that require large volumes of heated make-up air such as machine shops, vehicle maintenance buildings, and chemical storage facilities, are good candidates for a transpired collector. A long-term storage warehouse that does not require ventilation, would not be a suitable candidate. Also, buildings that have 100% recirculation/ filtration systems would be unsuitable.

Heat recovery systems, which are common in many modern office buildings (but less common in industrial buildings), also preheat ventilation air. As such—because of redundancy of function—buildings with existing heat recovery systems may not be suitable for transpired collector applications.

Field Experience

As of 1997, approximately 40 transpired collector systems have been installed in the private sector and on two Federal sites—two systems at Fort Carson, Colorado, and one at the National Renewable Energy Laboratory (NREL) in Golden, Colorado. Three of the 40 installations—the General Motors (GM) of Canada Oshawa Battery Plant, the Ford Plant in Oakville, Canada, and NREL—have been monitored extensively.

The installation at NREL is an ideal application of transpired collector technology. The facility is a 1300-square-foot (ft^2) chemical waste storage building that requires a ventilation rate of 3000 cfm to maintain safe indoor conditions. Also, because of the danger of combustion, open flames are prohibited in the building, so outside air is heated with electricity instead of gas. The 300-ft^2 transpired collector saves about 14,310 kWh annually (25.7% of the energy required to heat the facility's ventilation air). With a local electric rate of $0.025/kWh, the annual savings equates to about $360. The installation has a simple payback of 4.7 years.

Case Study

The GM Battery Plant in Oshawa, Canada, is a 100,000-ft^2 facility in which automotive batteries are manufactured. The plant was built in the 1970s and consists of an open shop floor and a 28-foot-high ceiling. GM operates two full-time production shifts within the plant and conducts maintenance activities at night and on weekends, so the building is continuously occupied. In 1991, plant management opted to install a transpired collector to correct the ventilation problems.

The monitoring program showed that the transpired collector saved GM 208,000 Btu per year for every square foot of installed solar collector. The majority of this savings—or 150,000 Btu/ft^2/year—resulted from the thermal energy gained directly by the outside air as it passed through the collector. The balance of the savings—or 58,000 Btu /ft^2/ year—came from recaptured heat loss through the wall clad with the transpired collector. The value of these savings depends on the heating source assumed to be displaced.

At the GM plant, steam was the existing primary heating source, but the system was incapable of providing the necessary quantities of heated outdoor air for ventilation. To redress the airflow problems with a steam option would have required the installation of a packaged rooftop steam-operated system with roof curb, steam piping, and outlet ducting. These systems are installed for about $2.16/cfm. To supply the same volume of air that the transpired collector supplies, the steam system would have to deliver 25,200 cfm and would cost $55,000. Also, the fan on the steam system would require an additional 3.6 kW to operate (compared to the transpired collector system), which would increase electricity costs by $1,430 annually.

Implementation Barriers

The biggest hurdle transpired collectors must overcome is user acceptance. Many solar technologies have been stigmatized by the rapid expansion of solar markets in the 1970s, when many poorly designed and poorly performing systems were deployed. Many potential users are reluctant to commit to a solar technology if a proven conventional option is available. Transpired collector technology has been proven to be a valid, reliable technology for reducing energy use and saving money, and the body of scientific data proving its effectiveness continues to grow.

Federal Technology Alert

Transpired Collectors (Solar Preheater for Outdoor Ventilation Air)

Simple, reliable technology can substantially reduce heating bills.

Abstract

Transpired collectors are a renewable energy technology that is well proven, is readily available, and has considerable potential for application at Federal facilities. Transpired collectors use solar energy to preheat ventilation (outdoor) air as it is drawn into a building. The technology is ideally suited for buildings with at least moderate ventilation requirements in sunny locations with long heating seasons.

Transpired collector technology is remarkably simple. A dark, perforated metal wall is installed on the south-facing side of a building, creating approximately a 6-inch (15-cm) gap between it and the building's structural wall. The dark-colored wall acts as a large solar collector that converts solar radiation to heat. Fans mounted at the top of the wall pull outside air through the transpired collector's perforations, and the thermal energy collected by the wall is transferred to the air passing through the holes. The fans then distribute the heated air into the building through ducts mounted near the ceiling. By preheating ventilation air with solar energy, the technology removes a substantial load from a building's conventional heating system, saving energy and money.

This *Federal Technology Alert* (FTA) of the New Technology Demonstration Program is designed to give Federal facility managers the information they need to decide whether they should pursue transpired collector technology for their facility.

This FTA describes the transpired collector, its energy-saving mechanisms, and the factors that influence its performance. Worksheets are included that let the reader perform the preliminary calculations to determine if a given facility is suitable for a transpired collector system and to determine the amount of energy such a system would save annually. The FTA contains a case study documenting the performance of the transpired collector installed at General Motors' battery plant in Oshawa, Canada. The document concludes with contacts for additional information and a list of articles, conference papers, and academic theses pertaining to the technology.


Warren Gretz, NREL/PIX04257

Figure 1. A transpired collector heating system being installed on a Federal Express facility in Littleton, Colorado.

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About the Technology

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Transpired collector technology is remarkably simple. A dark, perforated metal wall is installed on the south-facing side of a building, creating approximately a 6-inch (15-cm) gap between it and the building's structural wall (see Figure 2). The dark-colored wall acts as a large solar collector that converts solar radiation to heat. Fans associated with the building's ventilation system mounted at the top of the wall draw outside air through the transpired collector's perforations, and the thermal energy collected by the wall is transferred to the air passing through the holes. The fans then distribute the heated air into the building through ducts mounted from the ceiling. By preheating outdoor air with solar energy, the technology removes a substantial load from a building's conventional heating system, saving energy and money.

A transpired collector is installed on all or part of a building's south-facing wall, where it will receive the maximum exposure to direct sunlight during the fall, winter, and spring. The size of the wall varies depending on heating and airflow requirements and climate, but in many applications, the transpired collector will cover the maximum south-facing area available. The amount of energy and money saved by a transpired collector depends on the type of conventional fuel being displaced, occupant use patterns, building design, length of heating season, and the availability of sunlight during the heating season. In general, each square foot of transpired collector will raise the temperature of 4 cubic feet per minute (cfm) by as much as 40°F, delivering as much as 240,000 Btu annually per square foot of installed collector.

In addition to the metal sheeting that captures solar energy, the transpired collector heating system includes air-handling and control components that supply the solar-heated air (see Figure 2). The ventilation system, which operates independently of a building's existing heating system, includes a constant-speed fan to draw air through the transpired collector and into the distribution duct. Engineers typically use a 3-horsepower, 32-inch blade fan with about 10,000-cfm capacity.

As shown in Figures 3 and 4, the transpired collector system also contains a bypass damper located directly in front of the fan inlet duct. During the summer months when ventilation air does not need to be heated, this damper opens, circumventing the air-heating system. The bypass damper automatically opens when the air outside reaches a predetermined temperature, usually about 64°F.

Conserval Systems, Inc., of Toronto, Ontario, and Buffalo, New York, is currently the only supplier of the technology. Conserval has been manufacturing and installing a range of heat recovery and solar products since 1977. They received the first patent for transpired collector technology in 1989.

Application Domain

As of 1997, about 40 transpired collector air-heating systems had been installed in locations around the world on apartment buildings, warehouses, airplane hangars, factories, and in many other applications. Three transpired collector systems are in

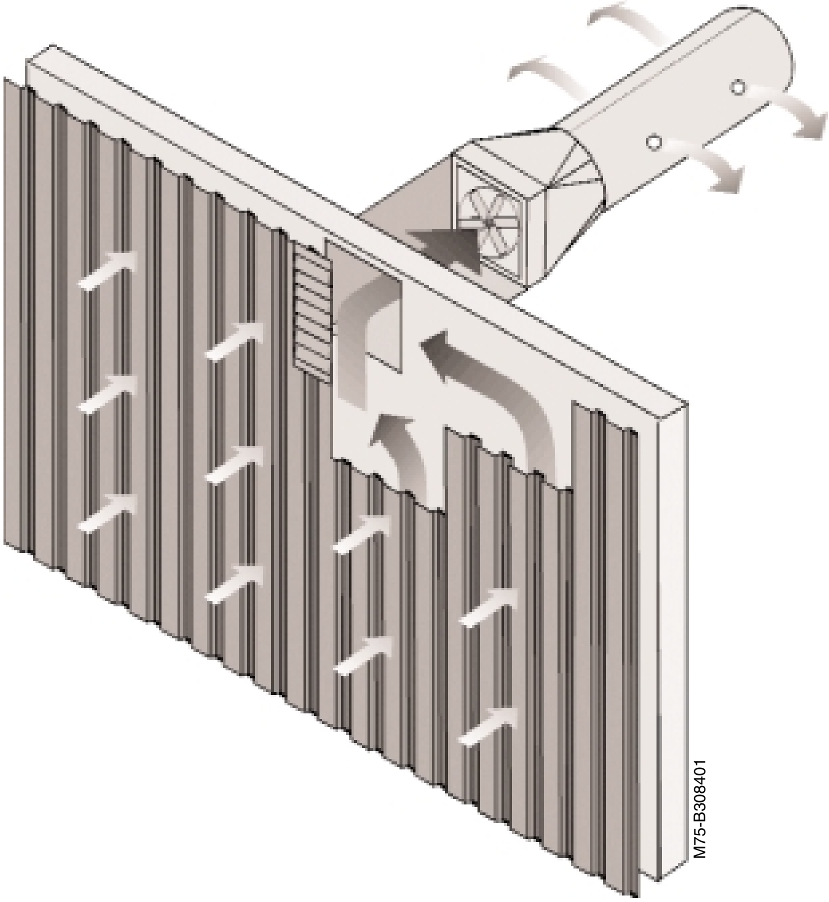


Figure 2. Transpired collector components.

A Wall by any Other Name...

The solar ventilation air-heating technology described in this *Federal Technology Alert* has been referred to by a variety of different names since it was first marketed in 1989. Conserval Engineering Inc., the company that holds the patent rights, refers to it as a "Solarwall®" heater. The research community, which has studied the technology in depth, refers to it as an "unglazed transpired solar collector" or "solar air-heating systems using perforated absorbers." In other literature it has been called "solar ventilation preheat system" or simply "transpired collectors."

In this document, we use the term "transpired collector" to refer to the technology described. The reader seeking additional information (see the "Literature" section on page 15) should not be confused by the different names by which the technology is presented in the scientific and popular literature.

use in the Federal sector—two at Fort Carson, Colorado, and another at the Waste Handling Facility at the National Renewable Energy Laboratory (NREL) in Golden, Colorado. High-profile industrial users include Ford Motor Company, General Motors Corporation (GM), McDonnell Douglas, and Federal Express.

The Federal-sector potential for this technology is considerable. Any heated building in a cool, sunny climate that has at least moderate ventilation requirements could benefit from a transpired collector. Buildings that require large volumes of heated make-up air, such as machine shops, vehicle maintenance buildings, and chemical storage facilities are good candidates. There are thousands of such facilities in the Federal sector.

Energy-Saving Mechanism

A transpired collector reduces the load on a building's heating system by heating intake air with solar energy. It preheats the ambient air by up to 40°F, reducing all or a portion of the load on a heating system during daylight hours. Although the transpired collector itself may not be able to achieve the required indoor air temperature on cloudy days or when the outside temperature plummets, it still provides useful energy and reduces utility bills.

The dark-colored transpired collector is a large solar collector, absorbing the solar energy striking it. The wall captures between 60% and 75% of the available solar energy, making it one of the most efficient solar collectors designed to date. In addition to capturing direct solar radiation, the transpired collector collects the indirect, scattered, and reflected sunlight known as diffuse solar radiation. Typically, diffuse solar radiation, which includes a portion of the radiation on clear days and all the radiation on overcast days, makes up about 25% of the total annual radiation at the Earth's surface.

The dark, corrugated metal sheets that make up the wall are 0.8-millimeter (mm)-thick and are typically manufactured from aluminum or galvinized steel. The perforations through which the air flows are 1.6 mm in diameter and are placed at regular intervals. The total percentage of the collector made up of these holes is referred to as the collector porosity.

In addition to meeting a portion of a building's heating load with clean, free solar energy, the transpired collector helps save energy and money in other ways. The collector recaptures heat loss through a building's south-facing wall; heat that escapes through the south wall is captured in the air space between the structural wall and the transpired collector and returned to the interior. Also, by introducing make-up air through ceiling-mounted ducts, the system eliminates the wasteful air stratification that often plagues high-ceiling buildings.

Other Benefits

The solar energy collected by a transpired collector displaces fossil fuel that would otherwise be burned to produce heated ventilation air. Greenhouse gas (CO_2) and acid rain emissions (SO_x and NO_x) are reduced proportionally. Electricity is consumed, though, by the distribution fans and dampers.

The transpired collector can also improve a building's appearance, giving the south-facing side a neat, clean, uniform look. Although initially many black transpired collectors were installed, other colors work well too, which gives the user some aesthetic options. The product is now available in a variety of shades, including brown, blue, gray, and red.

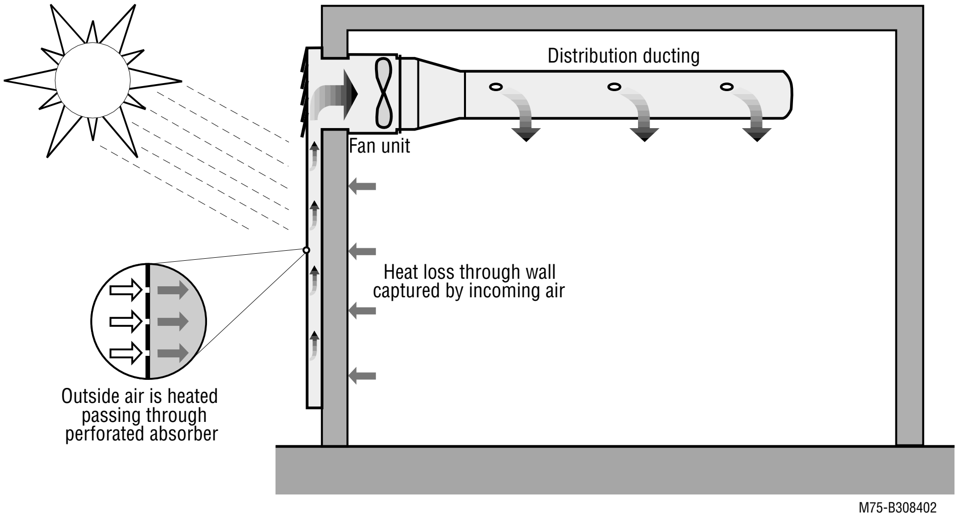


Figure 3. Transpired collector operation during the winter months.

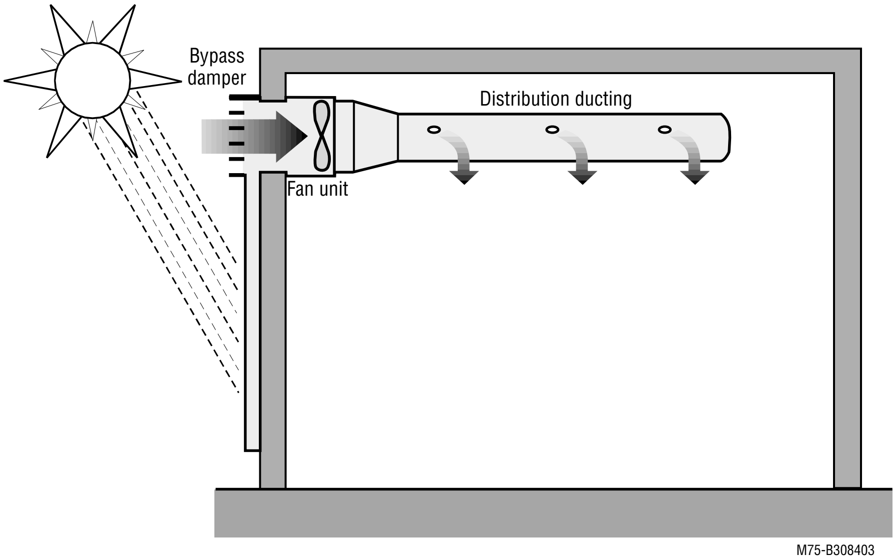


Figure 4. Transpired collector operation during the summer months.

Installation

The transpired collector attaches to a building's existing structure. The building frame is usually sufficient to support the collector sheeting, so racking requirements and construction costs are minimized. Although many transpired collectors have been installed as retrofits, the system economics improve if installation takes place during initial construction or building renovation. The system payback period can be reduced by up to half if the transpired collector installation can be incorporated with other construction work.

The transpired collector is attached to the structural wall with a support grid of vertical and horizontal Z-channels. These channels are perforated to accommodate airflow between the collector and the structural wall. The vertical channels are attached to the existing wall, the horizontal channels are attached to the vertical channels, and the perforated metal sheets are affixed to the horizontal channels.

The fan unit, which includes the fan, dampers, and thermostat controls, is mounted directly to the interior side of the south-facing wall. For each fan unit installed, a hole must be cut through the structural wall to allow air to flow into the building. A minimal amount of sheet-metal ducting is required to form a proper seal between the fan and the wall.

Installation time varies depending on a building's structural design and the total collector area being installed, but retrofit installations typically require 10 to 14 days.

Building codes and regulations pertaining to issues such as the location of outdoor air openings, weather protection for ducts on the building exterior, minimum duct thickness, and criteria for multistory applications should be addressed on an installation-by-installation basis. The applicability of codes may vary based on building height and area, construction type, and use group.

Federal-Sector Potential

The potential savings to be achieved by use of this new technology were estimated as part of the technology-screening process of the New Technology Demonstration Program.

Technology-Screening Process

The new technologies presented in the *Federal Technology Alert* series were identified through trade journals and through direct correspondence. Numerous responses were obtained from manufacturers, utilities, trade associations, research institutes, Federal sites, and other interested parties. Based on these responses, the technologies were evaluated in terms of potential Federal-sector energy savings and procurement, installation, and maintenance costs. They were also categorized as either just coming to market ("unproven" technologies) or as technologies for which field data and experience exist. Transpired collectors were judged to be life-cycle cost effective (at one or more Federal sites) in terms of installation cost, net present value, and energy savings. Several other proven technologies have been slated for further study through *Federal Technology Alerts*.

Estimated Savings and Market Potential

Figure 5 shows the average payback periods for transpired collector systems in three different geographic locations based on three different prices for natural gas. The data were derived from analyses conducted by Science Applications International Corporation (SAIC), which, in conjunction with the International Energy Agency, has developed a spreadsheet model to estimate economics of transpired collectors in different climates. The model outputs simple payback periods, taking into account the cost of auxiliary heating fuel, the cost of electricity to operate the fan, the geographic location, and the building type.

SAIC has used this model to compare paybacks at three locations—with greatly differing climates—in the United States: Denver, Colorado; Washington, D.C.; and Syracuse, New York. The model produced payback comparisons for a range of energy costs, from \$3/MBtu for natural gas to \$24/MBtu for electricity (\$0.08/kilowatt-hour [kWh]). These paybacks assume the collector was installed during building construction and assume a net installed cost of $\$5/\text{ft}^2$ (see discussion of costs on page 7). Payback periods for retrofit installations—which would have a net cost of approximately $\$10/\text{ft}^2$ —would be twice those for new installations.

Laboratory Perspective

Researchers at NREL in Golden, Colorado, have been studying transpired collector technology since 1989. In fact, researchers at NREL and engineers at Conserval simultaneously—and independently—developed the concept of using unglazed, perforated metal sheets as solar collectors for heating air. Since that time, researchers have improved the efficiency of the technology and gained a fundamental understanding of its heat transfer and airflow characteristics. The technology has been the subject of a number of dissertations conducted at universities in the United States and Canada. These investigations and other relevant publications are cited in the Literature section on page 15.

The research community has monitored and continues to monitor a number of the transpired collectors in use in both the Federal and private sectors. These monitoring programs have demonstrated that transpired collector technology is a reliable and effective way to save energy. They have also demonstrated that the current methods used to estimate the performance of the technology are valid.

Application

This section addresses technical aspects of applying transpired collector technology. The range of applications and climates in which transpired collector technology can best be applied are addressed. Design and integration considerations are discussed, including equipment and installation costs, installation details, maintenance, and codes and standards.

Application Considerations

The following subsections briefly discuss the prerequisites for a successful transpired collector application and the factors that influence project cost-effectiveness.

Application Prerequisites

- **Suitable South-Facing Wall**—A sufficient area of suitable south-facing exterior wall is required for installing the transpired collector's metal cladding. A wall with a high percentage of window or door area will likely be unsuitable, as will a wall that is heavily shaded throughout the day. A facade does not have to face true south for a transpired collector to operate effectively. Any wall within 45 degrees of true south will work, but the best performance is realized when the wall is within 20 degrees of true south.

- **Ventilation Load—**A candidate building for a transpired collector must have a minimum ventilation requirement. A long-term storage warehouse, for example, would not be a suitable application, because such a structure would not have to be ventilated. Also, buildings that have 100% recirculation/filtration systems would be unsuitable. The Project Scale section, below, discusses the influence of ventilation loads on the cost-effectiveness of an application.
- **The Absence of a Heat Recovery System—**Heat recovery systems, which are common in many modern office buildings (but less common in industrial buildings), also preheat ventilation air. Because of redundancy of function, buildings with existing heat recovery systems may not be suitable for transpired collector applications.

Cost-Effectiveness Factors

The following paragraphs present the major factors influencing the cost-effectiveness of transpired collector applications. The worksheets presented in the Sizing and Energy-Savings Calculations section (pages 9–11) provide quantitative estimates of energy savings.

- **The Cost of Conventional Energy—**The cost of the conventional energy used for space heating has a dramatic impact on the overall cost-effectiveness of a transpired collector application. What kind of energy is being displaced by the thermal energy supplied by the transpired collector and how much does that conventional energy cost? The price of conventional energy (that is, electricity, fossil fuels, or steam) can vary greatly from season to season and from region to region. The higher the price of the conventional energy used for space heating, the more cost effective the transpired collector application becomes.
- **Climate—**Transpired collectors are most cost effective in sunny climates with long heating seasons.
- **Project Scale—**Although transpired collectors have been installed on many large industrial buildings, they can also be cost effectively applied to smaller structures. A key to a successful application is the building's ventilation rate. For example, a small building with a large outdoor-air ventilation rate, such as a machine shop, might be as good an application as a large manufacturing facility that has only a moderate ventilation rate. (Consult American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 62 for recommended ventilation requirements.) Keep in mind that small transpired collector installations will have proportionally higher construction costs, and that below a certain collector size—depending on the factors influencing project cost-effectiveness—construction costs will become prohibitive.
- **New Construction versus Retrofit—**Installing a transpired collector during building construction can reduce system costs by as much as 50% compared to a retrofit application.

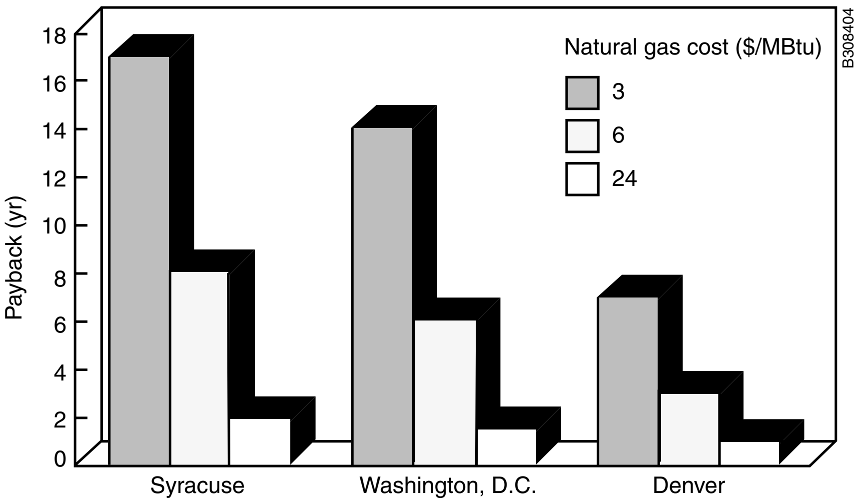


Figure 5. Payback periods for transpired collectors for three different locations and natural gas costs.

Where to Apply

The following are the most common transpired collector applications:

- Manufacturing plants
- Vehicle maintenance facilities
- Hazardous waste storage buildings
- Gymnasiums
- Airplane hangars
- Schools
- Warehouses requiring ventilation

What to Avoid

The following is a list of general applications and conditions that preclude the cost-effective use of transpired collector technology:

- Outdoor air not required
- Shaded or insufficient south-facing wall area
- Buildings with existing heat recovery systems
- Locations with short heating seasons
- Multiple-story buildings (because of possible problems with fire codes).

Equipment Integration

The transpired collector system operates independently of a building's existing heating system (but may utilize existing ventilation fans and ducts). The only integration issues that arise are associated with installing the collector and the air-handling components onto the building's existing frame (see page 5, "Installation").

Maintenance

Transpired collectors are very reliable. They have no moving parts (other than the ventilation fans and dampers, which would be part of any ventilation system). There are no problems from leaking, freezing, or overheating, and to date, no problems have been reported from users in the field regarding holes becoming plugged or degradation of the absorber surface. Even if the collector becomes dented, performance is not affected.

Equipment Warranties

The fan is covered by a 1-year manufacturer's warranty, and the color coatings used on the collector sheeting are warranteed for 20 years.

Codes and Standards

With regard to fire codes, transpired collectors have been deemed safe for single-story applications, and the polyethylene air distribution duct meets the fire code for flame-retardant materials.

Building codes and regulations pertaining to issues such as the location of outdoor air openings, weather protection for ducts on the building exterior, minimum duct thickness, and criteria for multistory applications should be addressed on an installation-by-installation basis. The applicability of codes may vary based on building height and area, construction type, and use group.

Costs

As a retrofit to an existing building, the typical cost of a system is approximately \$10 to \$12/ft^2 of installed wall. About 60% of this figure comprises material costs and 40% comprises labor, which includes the installation of the collector and the air-handling components. Table 1 shows a breakdown of costs for a transpired collector system in a retrofit application.

In new buildings, builders can use lower-cost facades underneath collector walls. Doing so will likely realize savings of \$3 to \$5/ft^2 by displacing more expensive facade material. Taking into account this material displacement credit, the installed cost of a collector on a new building is in the range of \$5 to \$7 per square foot.

Table 1. Installation Costs of a Retrofit Transpired Collector

Absorber	\$ 3.50/ft^2
Supports, flashing, etc.	\$ 2.50/ft^2
Installation	\$ 4.00/ft^2
Other costs	\$ 1.00/ft^2
Total	\$11.00/ft^2

Utility Incentives

Utilities offer no incentives for using this technology.

Technology Performance

Transpired collector owners are generally pleased with their systems. Based on the savings and improved ventilation created by the transpired collector installed on its plant in Oakville, Canada, Ford Motor Company installed five more systems on plants in the United States and Canada.

Field Experience

As of 1997, approximately 40 transpired collector systems had been installed in the private sector, and on two Federal sites—two systems at Fort Carson, Colorado, and one at NREL in Golden, Colorado (see Figures 6 and 7). Three of these installations—the General Motors of Canada Oshawa Battery Plant, the Ford Plant in Oakville, Canada, and NREL—have been monitored extensively. Table 2 lists the transpired collector heating systems in use around the world.

The installation at NREL (shown in Figure 7) is an ideal application of transpired collector technology. The facility is a 1300-ft^2 chemical waste storage building that requires a ventilation rate of 3000 cfm to maintain safe indoor conditions. Also, because of the danger of combustion, open flames are prohibited in the building, so outside air is heated with electricity instead of gas. The 300-ft^2 transpired collector saves about 14,310 kWh annually (25.7% of the energy required to heat the facility's ventilation air). With a local electric rate of \$0.025/kWh, the annual savings equates to about \$360. The installation has a simple payback of 4.7 years.

Energy Savings

The transpired collector at the Ford assembly plant in Oakville, Canada, was installed in 1990. The 20,000-ft^2 transpired collector system supplies heated air to a 28,000-ft^2 area with a ceiling as high as 45 feet in places. The system produces 5811 MBtu of energy savings, worth about \$30,000 U.S. annually. This savings represents about 17% of the plant's annual air-heating costs. The transpired collector system paid for itself in a little more than 5 years.

The transpired collector on the GM plant was installed in 1991 with a total collector area of 4520 ft^2. The GM system heats an area of 39,000 ft^2, and supplies 940 MBtu of energy savings annually. This system saves GM approximately \$10,200 per year. The system is discussed in more detail in the Case Study on page 13.

Maintenance

Reports from system owners in the field demonstrate that transpired collectors are mostly maintenance free. Except for servicing of air distribution units (fan belts, lubrication), the systems require minimal maintenance.

Awards and Recognition

A transpired collector was an important part of a comprehensive energy management program at Fort Carson, Colorado. The Department of the Army installed a collector on an aviation hangar. The collector, combined with lighting and occupancy sensors,

Warren Gretz, NREL/PIX00599

Figure 6. The transpired collector on the Avum Hangar at Fort Carson, Colorado.

Table 2. Transpired Collector Installations

PLANT NAME	LOCATION	SIZE	YEAR
CANMET	Ontario, Canada	7,500 ft^2	1997
Ft. Carson Battery Storage Building	Colorado Springs, Colorado, U.S.	300 ft^2	1997
Ontario Hydro and Maintenance Building	Ontario, Canada	800 ft^2	1997
Ontario Ministry of Housing	Ontario, Canada	1,350 ft^2	1997
Spices Board of India, spice drying test	Cochin, India	100 ft^2	1997
Steeltech Building Products Inc., metal fabrication plant	Bloomfield, Connecticut, U.S.	6,200 ft^2	1997
Canadair Division of Bombardier Airplane Manufacturer	Quebec, Canada	108,000 ft^2	1996
Federal Express	Littleton, Colorado, U.S.	5,000 ft^2	1996
Ontario Hydro and Maintenance Building	Ontario, Canada	800 ft^2	1996
Avum Hanger	Colorado Springs, Colorado, U.S.	7,800 ft^2	1995
Bombardier	Quebec, Canada	5,000 ft^2	1995
Bombardier	Quebec, Canada	5,000 ft^2	1995
Bombardier Inc., Rail Cars Manufacturer	Quebec, Canada	4,420 ft^2	1995
Canadian Tool & Die	Winnipeg, Canada	5,400 ft^2	1995
Domco Manufacturing Plant	Quebec, Canada	1,880 ft^2	1995
Ford New Holland Tractor Factory	Manitoba, Canada	22,000 ft^2	1995
Joint Reasearch Centre Engineering Research Facility	Italy	5,630 ft^2	1995
Office Building	Switzerland	5,000 ft^2	1995
Ontario Hydro North West Hydroelectric Headquarters	Ontario, Canada	700 ft^2	1995
Ontario Ministry of Housing	Ontario, Canada	4,500 ft^2	1995
Stampsli Factory	Switzerland	1,000 ft^2	1995
Versatile Farm Equipment (Ford New Holland) Tractor Manufacturer	Manitoba, Canada	21,700 ft^2	1995
ASEAN-Canade Project on Solar-Energy-Drying Processes, Tea-Processing Plant	Malaysia	3,990 ft^2	1994
AVEDA Corporation	Blaine, Minnesota, U.S.	1,270 ft^2	1994
Centre D’Enseignement Professional School	St. Hyacinthe, Pennsylvania, U.S.	6,800 ft^2	1994
Ontario Ministry of Housing	Ontario, Canada	3,580 ft^2	1994
Bombardier Inc., Manufacturing Plant	Quebec, Canada	12,900 ft^2	1993
C.I.M.I.C. Secondary Public School	Quebec, Canada	1,330 ft^2	1993
Eder	Volkermarket, Austria	2,260 ft^2	1993
General Motors of Canada Wastewater Plant	Ontario, Canada	2,700 ft^2	1993
Ontario Ministry of Housing	Canada	1,200 ft^2	1993
Ontario Ministry of Housing	Ontario, Canada	2,820 ft^2	1993
Stadtwerke Gottingen Cogeneration Plant	Gottingen, Germany	3,980 ft^2	1993
Acier CMP Steel Service Centre	Quebec, Canada	4,225 ft^2	1992
General Motors of Canada Oshawa Battery Plant	Ontario, Canada	4,680 ft^2	1992
National Renewable Energy Laboratory	Golden, Colorado	351 ft^2	1991
Ensite Engine Plant	Ontario, Canada	10,500 ft^2	1990
Ford Motor Company of Canada Oakville Assembly Plant	Ontario, Canada	20,000 ft^2	1990

Warren Gretz, NREL/PIX00147

Figure 7. The transpired collector on the Waste Handling Facility at the National Renewable Energy Laboratory in Golden, Colorado.

digital controls, and boiler and motor replacements, saved 31.3 Btu and lowered energy costs by $144,800. This savings was recognized with a 1997 Federal Energy and Water Management Award from the U.S. Department of Energy (DOE).

R&D magazine awarded Conserval, Inc., and researchers at NREL its prestigious R&D 100 Award, recognizing transpired collector technology as one of the 100 most important advances of 1994 (the year the nomination was submitted).

Popular Science also recognized the technology's potential when it awarded Conserval and NREL its 1994 "Best of What's New" Award.

In 1992, DOE's Energy-Related Inventions Program rated the transpired collector in the top 2% of energy inventions.

Conserval Systems, Inc., has received a number of awards from Canadian organizations, including the Toronto Construction Association's Best New Building Product of the Year Award in 1994 and a Certificate of Recognition for development and commercialization of the technology from Natural Resources Canada.

Sizing and Energy-Savings Calculations

Figure 8 through Figure 11 present worksheets and supporting data that help calculate the optimum size of a transpired collector for a given facility and estimate the amount of energy that will be saved annually with the system.

Figure 8 is a worksheet for determining the size of the collector based on a facility's available south-facing wall and its outdoor requirement.

Figure 9 is a worksheet for estimating the amount of energy a transpired collector will save annually based on the size of the collector, the facility's operating and performance characteristics, and geographic location.

The map in Figure 10 presents the estimated annual Btu output per square foot of collector for geographic regions in the United States. This data is used in the annual energy-savings worksheet in Figure 9. The energy output data presented on the map are a function of solar radiation and length (and severity) of the heating season.

The map in Figure 11 shows the average annual heating degree-days for geographic regions in the United States; it too is used in the energy-savings calculation.

Appendix A provides examples of completed sizing and energy-savings worksheets.

Collector Sizing

Collector sizing depends on the magnitude of the building ventilation and the wall area available for mounting the transpired solar collector.

V_{bldg} = building outdoor airflow rate ________ cfm

A_{avai} = available wall area for collector ________ ft^2

v_{min} = minimum collector flow rate (typically about 8 cfm/ft^2) ________ cfm/ft^2

v_{max} = maximum collector flow rate (typically about 8 cfm/ft^2) ________ cfm/ft^2

A_{min} = minimum collector area (ft^2)

A_{max} = maximum collector area (ft^2)

A_{coll} = design collector area (ft^2)

V_{coll} = total flow rate through the collector (cfm)

v_{coll} = flow rate per unit collector area (cfm/ft^2)

$A_{min} = \underset{V_{bldg}}{\underline{\qquad}} \div \underset{V_{max}}{\underline{\qquad}}$ = ________ ft^2

$A_{max} = \underset{V_{bldg}}{\underline{\qquad}} \div \underset{V_{min}}{\underline{\qquad}}$ = ________ ft^2

1) if $A_{avail} > A_{max}$, then

$A_{coll} = A_{max}$ = ________ ft^2

$V_{coll} = V_{bldg}$ = ________ cfm

$v_{coll} = v_{min}$ = ________ cfm/ft^2

2) if $A_{min} < A_{avail} < A_{max}$, then

$A_{coll} = A_{avail}$ = ________ ft^2

$V_{coll} = V_{bldg}$ = ________ cfm

$v_{coll} = V_{bldg} \div A_{avail}$ = ________ cfm/ft^2

3) if $A_{avail} < A_{min}$, then

$A_{coll} = A_{avail}$ = ________ ft^2

$V_{coll} = A_{avail} \times v_{max}$ = ________ cfm

$v_{coll} = v_{max}$ = ________ cfm/ft^2

Figure 8. Collector sizing worksheet.

Annual Energy Savings

A_{coll} = collector area ________ ft^2

t_{hours} = time that there is airflow through the collector (length of collector operating day) ________ hours/day

t_{days} = time that there is airflow through the collector (length of collector operating week) ________ days/week

t_{weeks} = time that there is airflow through the collector (length of collector operating season) ________ weeks/year

q_{solar} = useful energy from the collector (from Map 1) ________ kBtu/ft^2-year

q_{fan} = fan energy for airflow through the collector (typically about 1 W/ft^2) ________ W/ft^2

U_{wall} = heat loss coefficient for the building wall ________ Btu/°F-ft^2-hour

HDD = annual heating degree-days (from Map 2) ________ °F-days/year

E_{htg} = efficiency of the conventional heating system ________ fraction

Q_{solar} = solar energy collected (MBtu/year)

Q_{wall} = wall heat recapture (MBtu/year) (only significant for very poorly insulated walls)

Q_{saved} = thermal energy savings (MBtu/year)

Q_{fan} = fan energy use (kWh/year)

Thermal Energy Savings:

$$Q_{solar} = \underset{A_{coll}}{\underline{\qquad}} \text{ x } \underset{q_{solar}}{\underline{\qquad}} \text{ x } (\underset{t_{days}}{\underline{\qquad}} \div 7) \div 10^3 = \underline{\qquad\qquad} \text{ MBtu/year}$$

$$Q_{wall} = \underset{A_{coll}}{\underline{\qquad}} \text{ x } \underset{U_{wall}}{\underline{\qquad}} \text{ x } \underset{t_{hours}}{\underline{\qquad}} \text{ x } (\underset{t_{days}}{\underline{\qquad}} \div 7) \text{ x } \underset{HDD}{\underline{\qquad}} \div 10^6 = \underline{\qquad\qquad} \text{ MBtu/year}$$

$$Q_{saved} = (\underset{Q_{solar}}{\underline{\qquad}} + \underset{Q_{wall}}{\underline{\qquad}}) \div \underset{E_{htg}}{\underline{\qquad}} = \underline{\qquad\qquad} \text{ MBtu/year}$$

Electrical Energy Parasitics:

$$Q_{fan} = \underset{A_{coll}}{\underline{\qquad}} \text{ x } \underset{q_{fan}}{\underline{\qquad}} \text{ x } \underset{t_{hours}}{\underline{\qquad}} \text{ x } \underset{t_{days}}{\underline{\qquad}} \text{ x } \underset{t_{weeks}}{\underline{\qquad}} \div 10^3 = \underline{\qquad\qquad} \text{ kWh/year}$$

Figure 9. Energy-savings worksheet.

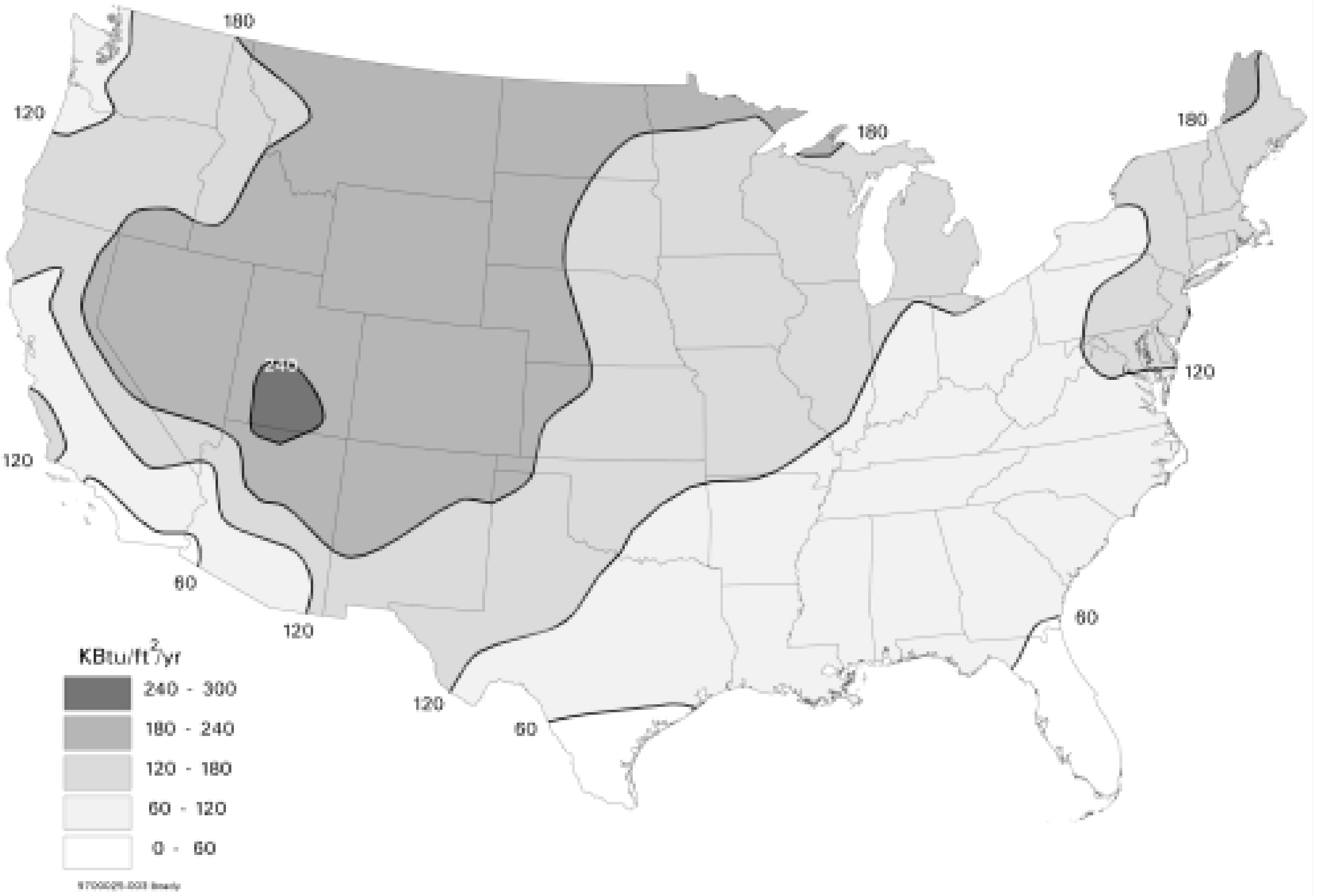


Figure 10. Useful energy delivered by the collector.

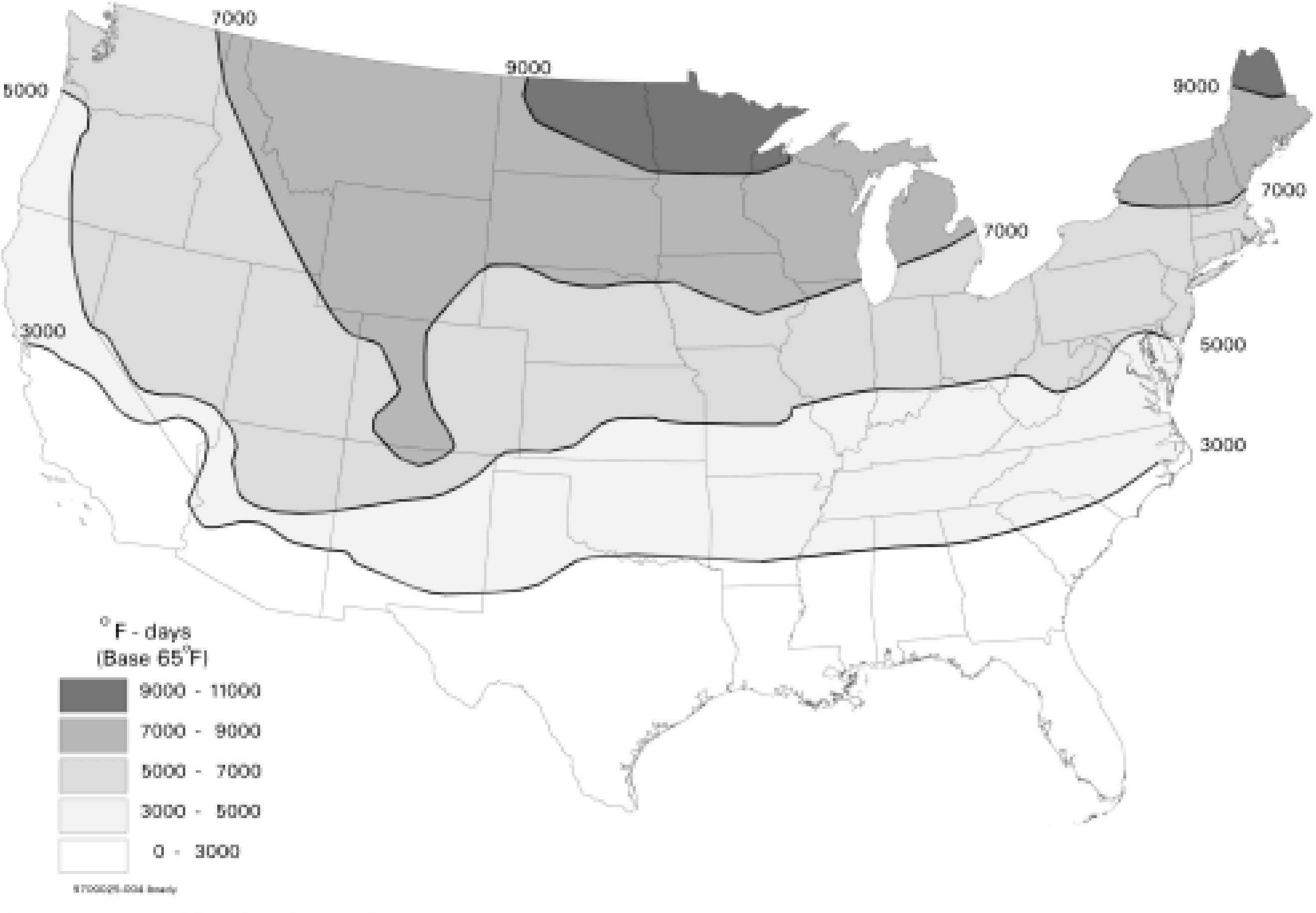


Figure 11. Annual heating degree-days.

Case Study—General Motors Battery Plant

Facility Description

The General Motors Battery Plant in Oshawa, Canada, is a 100,000-ft^2 facility in which automotive batteries are manufactured. The plant was built in the 1970s and consists of an open shop floor and a 28-foot-high ceiling. GM operates two full-time production shifts within the plant and conducts maintenance activities at night and on weekends, so the building is continuously occupied.

Existing Technology Description

Until the early 1990s, GM relied solely on a steam-operated fan coil system for space heating, but the system was incapable of providing the necessary quantities of heated outdoor air. As a result, the plant was not being adequately ventilated.

New Technology Description

In 1991, plant management installed a transpired collector (see Figure 12) to correct the ventilation problems. During the following 2 years the transpired collector system was modified slightly to improve airflow; the original fans and motors were replaced with vane axial fans and high-efficiency motors, and the original ducting was replaced with the upgraded fabric ducting.

The GM plant collector comprises 4520 ft^2 of absorber sheeting. The lower 21 feet of the transpired collector is black, perforated, aluminum wall cladding with 1.6-mm holes totaling 2% porosity. The average depth of the plenum between the transpired collector and the plant's structural wall is 6 inches. The canopy at the top of the wall acts as both a manifold for the airflow and a solar heat collection device. The canopy face is made of perforated plate with 1% porosity. The transpired collector covers about 50% of the total area of the plant's south-facing wall; the remainder of the south facade has shipping doors and other obstructions that make it unsuitable for mounting collector cladding.

The GM transpired collector has two fan/distribution systems, each consisting of a constant-speed fan, a recirculation damper system, and a fabric distribution duct. The total airflow delivered by the system's fans is 40,000 cfm. Both recirculated air and air drawn through the solar collectors make up this flow; the percentages of each depend on the temperature of the air coming from the collector.

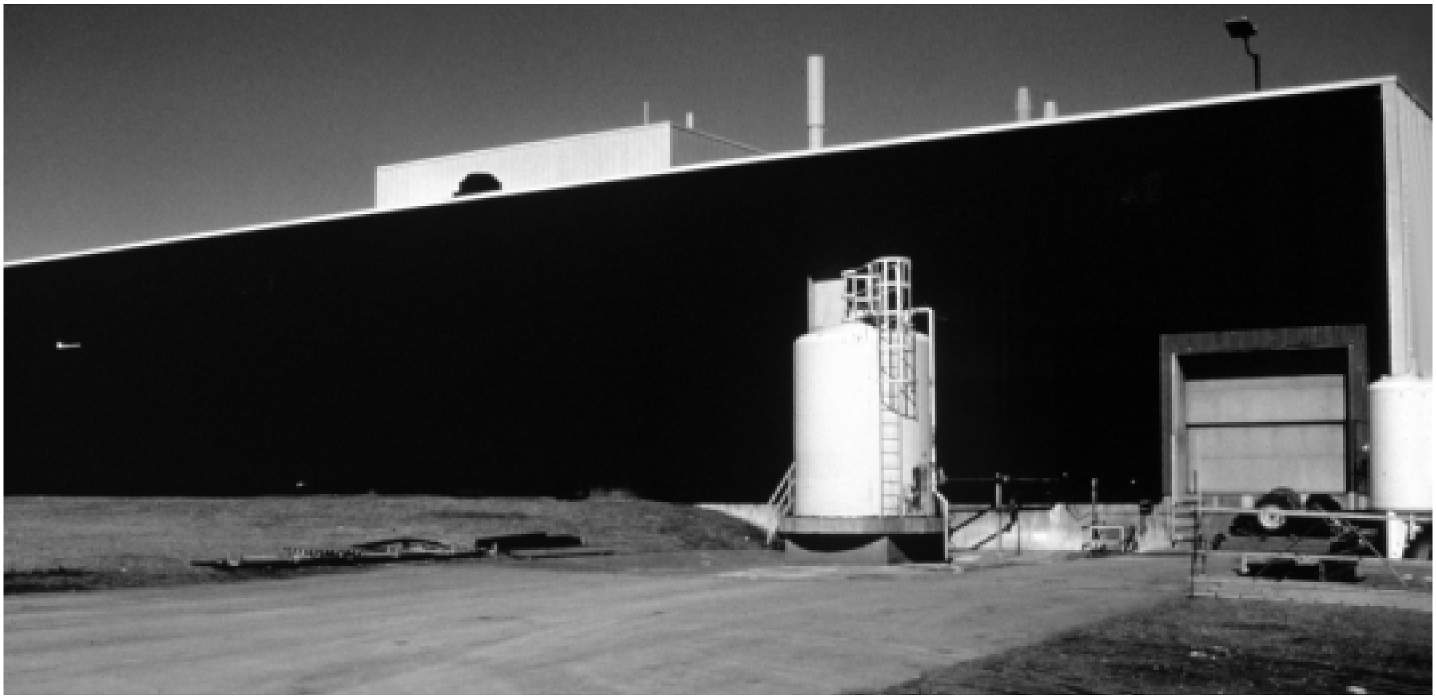
Energy Savings

The GM Battery Plant's transpired collector has been monitored extensively since it was installed. The data in this case study reflect the performance of the system during the 1993/94 heating season after the previously mentioned modifications had been completed. An in-depth report on the monitoring program is available (Enermodal Engineering Ltd. 1995).

The data shows that the annual energy savings for the 4520-ft^2 collector was 940 million Btu/year (see Table 3): 678 MBtu resulted from the thermal energy gained directly from the outside air as it passed through the absorber (Qsolar); and 262 MBtu resulted from heat loss recaptured by the wall (Qwall) from inside the building. Other possible energy-saving mechanisms—such as destratification and heat recapture—likely contributed to improved system performance; however, these effects are highly structure-specific and have not been incorporated into the savings reported here.

Life-Cycle Cost

The cost of the transpired collector system at the GM plant was $66,530, or $14.72/ft^2 of installed collector. The cost per square foot is higher than typical installations for two reasons: 1) this system was installed soon after the technology was introduced, before design and installation procedures had been streamlined, and 2) the cost includes the fan and ducting modifications that were implemented during the first 2 years of operation.



Conserval Systems, Inc./PIX04030

Figure 12. The transpired collector on the GM Battery Plant in Oshawa, Canada.

Table 3. Savings from the GM Transpired Collector*

Energy-Saving Mechanism	MBtu/year
Active Solar Heating	678
Recaptured Wall Heat Loss	262
Total Energy Savings	940

*The data presented in this table were derived from Enermodal Engineering Limited, 1995, Performance of the Perforated-Plate/Canopy Solarwall at GM Canada, Oshawa, DSS Contract No. 007 SQ 23440-1-9552, Energy Technology Branch, CANMET, Department of Natural Resources Canada, Ottawa, Ontario.

Based on a National Institute of Standard Technology (NIST) Building Life-Cycle Costing (BLCC) comparative economic analysis (see Appendix C), the present value of life-cycle savings is $64,574, for a savings-to-investment ratio of 1.97. Therefore, the project is cost effective according to Federal criteria (W CFR 43G). The simple payback period is 6 years. (See the Federal Life-Cycle Costing Procedures in Appendix B and the NIST BLCC Comparative Economic Analysis in Appendix C.)

Performance Shakeout

The GM transpired collector had a number of operational problems. After the system was initially installed, employees complained about fan noise and cold drafts, and they occasionally disabled the system. The fan and duct upgrades described previously eliminated the problems on one of the fan systems; the other fan continues to generate noise, and employees still disable it when working in the immediate vicinity. Conserval has addressed these complaints by specifying smaller, but more numerous, fans in subsequent installations.

Also, both bypass dampers and a recirculation damper required additional maintenance. The recirculation damper became stuck in full recirculation mode, and a new modulating motor was installed to fix the problem. The bypass dampers occasionally became bound, which led to unacceptably high leakage rates. These dampers were kept closed manually throughout the 1993–1994 heating season.

The Technology in Perspective

Transpired collectors have potential for widespread use in the Federal sector, with thousands of warehouses, hangars, storage facilities, vehicle maintenance shops, hazardous material storage, and other ventilation-intensive structures.

Users in the Federal sector can realize a number of advantages from transpired collector technology. First, by reducing the amount of conventional energy used to heat ventilation air, system users save money. Second, by replacing heat derived from fossil fuels with heat derived from clean solar energy, users are reducing the detrimental environmental side effects, such as the production of greenhouse gases (plus NO_x and SO_x) associated with the burning of fossil fuels. Third, the technology is remarkably simple and maintenance free; the system makes few additional demands on the facility's engineering or maintenance staff.

The Technology's Development

Prior to 1989, solar air-heating systems resembled flat-plate water-heating systems. These early systems contained a dark metal absorber, but they also had glazing—a transparent cover—that prevented heat loss to the atmosphere. Rather than pull air through the absorber, these systems heated the air flowing parallel to the absorber. Compared to transpired collector technology, these systems were less efficient because solar radiation was reflected off the glazing and they had comparatively poor heat transfer from the absorber to the air. They were also more expensive because of the added material cost.

The transpired collector design, developed simultaneously at Conserval, Inc., and NREL in 1989, represented a major breakthrough in solar air-heating technology. By eliminating the glazing and pulling air through the absorber, researchers were able to greatly improve efficiencies and reduce system costs. Since the initial breakthrough, researchers and engineers have continued to improve system performance by optimizing the size and spacing of the perforations and developing methods to ensure uniform airflow through the absorber.

Technology Outlook

The future will likely see increased use of transpired collectors in the Federal and private sectors. The biggest hurdle the technology must overcome is user acceptance. Many solar technologies have been stigmatized by the rapid expansion of solar markets in the 1970s, when many poorly designed and poorly performing systems were deployed. Many potential users are reluctant to commit to a solar technology if a proven conventional option is available. Transpired collector technology has been proven to be valid and reliable for reducing energy use and saving money, and the body of scientific data proving its effectiveness continues to grow.

Further dramatic improvements in efficiency are unlikely; transpired collectors are already among the most efficient solar collectors available, converting between 65% and 75% of the available solar energy.

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Peter, R.; Hollick, J. U.S. Patent No. 4,899,728. (13 February 1990). Method and Apparatus for Preheating Ventilation Air for a Building.

Appendixes

Appendix A: Worksheets From Figures 8 and 9 Completed for a Hypothetical Building in Chicago, Illinois.

Appendix B: Federal Life-Cycle Costing Procedures and BLCC Software

Appendix C: General Motors Solar Ventilation Heat Case Study NIST BLCC Comparative Economic Analysis

Appendix A: Collector Sizing

Collector sizing depends on the magnitude of the building ventilation and the wall area available for mounting the transpired solar collector.

V_{bldg} = building outdoor airflow rate **12,000** cfm

A_{avai} = available wall area for collector **2,000** ft^2

v_{min} = minimum collector flow rate (typically about 8 cfm/ft^2) **4** cfm/ft^2

v_{max} = maximum collector flow rate (typically about 8 cfm/ft^2) **8** cfm/ft^2

A_{min} = minimum collector area (ft^2)

A_{max} = maximum collector area (ft^2)

A_{coll} = design collector area (ft^2)

V_{coll} = total flow rate through the collector (cfm)

v_{coll} = flow rate per unit collector area (cfm/ft^2)

$$A_{min} = \underset{V_{bldg}}{\underline{\mathbf{12{,}000}}} \div \underset{V_{max}}{\underline{\mathbf{8}}} = \underline{\mathbf{1{,}500}}\ \text{ft}^2$$

$$A_{max} = \underset{V_{bldg}}{\underline{\mathbf{12{,}000}}} \div \underset{V_{min}}{\underline{\mathbf{4}}} = \underline{\mathbf{3{,}000}}\ \text{ft}^2$$

1) if $A_{avail} > A_{max}$, then

$A_{coll} = A_{max}$ = ________ ft^2

$V_{coll} = V_{bldg}$ = ________ cfm

$v_{coll} = v_{min}$ = ________ cfm/ft^2

2) if $A_{min} < A_{avail} < A_{max}$, then

$A_{coll} = A_{avail}$ = **2,000** ft^2

$V_{coll} = V_{bldg}$ = **12,000** cfm

$v_{coll} = V_{bldg} \div A_{avail}$ = **6** cfm/ft^2

3) if $A_{avail} < A_{min}$, then

$A_{coll} = A_{avail}$ = ________ ft^2

$V_{coll} = A_{avail} \times v_{max}$ = ________ cfm

$v_{coll} = v_{max}$ = ________ cfm/ft^2

Annual Energy Savings

A_{coll}	=	collector area	**2,000**	ft^2
t_{hours}	=	time that there is airflow through the collector (length of collector operating day)	**16**	hours/day
t_{days}	=	time that there is airflow through the collector (length of collector operating week)	**5**	days/week
t_{weeks}	=	time that there is airflow through the collector (length of collector operating season)	**35**	weeks/year
q_{solar}	=	useful energy from the collector (from Map 1)	**120**	kBtu/ft^2-year
q_{fan}	=	fan energy for airflow through the collector (typically about 1 W/ft^2)	**1**	W/ft^2
U_{wall}	=	heat loss coefficient for the building wall	**0.1**	Btu/°F-ft^2-hour
HDD	=	annual heating degree-days (from Map 2)	**5,000**	°F-days/year
E_{htg}	=	efficiency of the conventional heating system	**0.7**	fraction
Q_{solar}	=	solar energy collected (MBtu/year)		
Q_{wall}	=	wall heat recapture (MBtu/year) (only significant for very poorly insulated walls)		
Q_{saved}	=	thermal energy savings (MBtu/year)		
Q_{fan}	=	fan energy use (kWh/year)		

Thermal Energy Savings:

$$Q_{solar} = \underset{A_{coll}}{\underline{\mathbf{2,000}}} \times \underset{q_{solar}}{\underline{\mathbf{120}}} \times (\underset{t_{days}}{\underline{\mathbf{5}}} \div 7) \div 10^3 = \underline{\mathbf{171}} \text{ MBtu/year}$$

$$Q_{wall} = \underset{A_{coll}}{\underline{\mathbf{2,000}}} \times \underset{U_{wall}}{\underline{\mathbf{0.1}}} \times \underset{t_{hours}}{\underline{\mathbf{16}}} \times (\underset{t_{days}}{\underline{\mathbf{5}}} \div 7) \times \underset{HDD}{\underline{\mathbf{5,000}}} \div 10^6 = \underline{\mathbf{11}} \text{ MBtu/year}$$

$$Q_{saved} = (\underset{Q_{solar}}{\underline{\mathbf{171}}} + \underset{Q_{wall}}{\underline{\mathbf{11}}}) \div \underset{E_{htg}}{\underline{\mathbf{0.7}}} = \underline{\mathbf{260}} \text{ MBtu/year}$$

Electrical Energy Parasitics:

$$Q_{fan} = \underset{A_{coll}}{\underline{\mathbf{2,000}}} \times \underset{q_{fan}}{\underline{\mathbf{1}}} \times \underset{t_{hours}}{\underline{\mathbf{16}}} \times \underset{t_{days}}{\underline{\mathbf{5}}} \times \underset{t_{weeks}}{\underline{\mathbf{35}}} \div 10^3 = \underline{\mathbf{5,600}} \text{ kWh/year}$$

Appendix B: Federal Life-Cycle Costing Procedures and the BLCC Software

Federal agencies are required to evaluate energy-related investments on the basis of minimum life-cycle costs (LCC) (10 CFR Part 436). A life-cycle cost evaluation computes the total long-run costs of a number of potential actions, and selects the action that minimizes the long-run costs. When considering retrofits, sticking with the existing equipment is one potential action, often called the baseline condition. The LCC of a potential investment is the present value of all of the costs associated with the investment over time.

The first step in calculating the LCC is to identify the costs. Installed cost includes cost of materials purchased and the labor required to install them (for example, the price of an energy-efficient lighting fixture, plus cost of labor to install it). Energy cost includes annual expenditures on energy to operate equipment. (For example, a lighting fixture that draws 100 watts and operates 2,000 hours annually requires 200,000 watt-hours [200 kWh] annually. At an electricity price of $0.10/kWh, this fixture has an annual energy cost of $20.) Non-fuel operation and maintenance (O&M) includes annual expenditures on parts and activities required to operate equipment (for example, replacing burned-out lightbulbs). Replacement costs include expenditures to replace equipment upon failure (for example, replacing an oil furnace when it is no longer usable).

Because LCC includes the cost of money, periodic and a-periodic O&M and equipment replacement costs, energy escalation rates, and salvage value, it is usually expressed as a present value, which is evaluated by

$$LCC = PV(IC) + PV(EC) + PV(OM) + PV(REP)$$

where PV (x) denotes "present value of cost stream x",
IC is the installed cost,
EC is the annual energy cost,
OM is the annual non-energy cost, and
REP is the future replacement cost.

Net present value (NPV) is the difference between the LCCs of two investment alternatives, e.g., the LCC of an energy-saving or energy-cost-reducing alternative and the LCC of the baseline equipment. If the alternative's LCC is less than the baseline's LCC, the alternative is said to have NPV, i.e., it is cost effective. NPV is thus given by

$$NPV = PV(EC_0) - PV(EC_1) + PV(OM_0) - PV(OM_1) + PV(REP_0) - PV(REP_1) - PV(IC)$$

or

$$NPV = PV(ECS) + PV(OMS) + PV(REPS) - PV(IC)$$

where subscript 0 denotes the baseline condition,
subscript 1 denotes the energy cost-saving measure,
IC is the installation cost of the alternative (the IC of the baseline is assumed to be zero),
ECS is the annual energy cost saving,
OMS is the annual non-energy O&M saving, and
REPS is the future replacement saving.

Levelized energy cost (LEC) is the break-even energy price (blended) at which a conservation, efficiency, renewable, or fuel-switching measure becomes cost effective ($NPV > = 0$). Thus, a project's LEC is given by

$$PV(LEC*EUS) = PV(OMS) + PV(REPS) - PV(IC)$$

where EUS is the annual energy use savings (energy units/yr). Savings-to-investment ratio (SIR) is the total (PV) saving of a measure divided by its installation cost:

$$SIR = (PV(ECS) + PV(OMS) + PV(REPS))/PV(IC)$$

Some of the tedious effort of LCC calculations can be avoided by using the BLCC software, developed by NIST. For copies of BLCC, call the FEMP Help Desk at (800) 363-3732.

Appendix C: General Motors Solar Ventilation Heat Case Study NIST BLCC Comparative Economic Analysis

```
*******************************************************************************
*     N I S T  B L C C:  COMPARATIVE  ECONOMIC  ANALYSIS (ver. 4.4-97 )      *
*******************************************************************************

      Project: General Motors Solar Ventilation Heat
      Basecase: Basecase
      Alternative: Solar Case

      Principal Study Parameters

      Analysis Type:           Federal Analysis—Energy Conservation Projects
      Study Period:            25.00 Years (Jan 1997 through Dec 2021)
      Discount Rate:           4.1% Real (exclusive of general inflation)
      Basecase LCC File:       GMBASCAS.LCC
      Alternative LCC File:    GMSOLAR.LCC


                          Comparison of Present-Value Costs

                                                                          Savings
                                                  Basecase   Solar Case  from Alt.
Initial Investment item(s):                     ----------  ----------  ----------
     Cash Requirements as of Service Date              $0     $66,530    -$66,530
                                                ----------  ----------  ----------
          Subtotal                                     $0     $66,530    -$66,530
Future Cost Items:
     Annual and Other Recurring Costs                  $0      $3,092     -$3,092
     Energy-related Costs                        $136,822      $2,627    $134,195
                                                ----------  ----------  ----------
          Subtotal                               $136,822      $5,718    $131,104
                                                ----------  ----------  ----------
     Total Present Value of Life-Cycle Cost      $136,822     $72,248     $64,574


Net Savings from Alternative Solar Case Compared to Alternative BaseCase


          Net Savings  =  P.V. of Noninvestment Savings     $131,104
                       -  Increased Total Investment         $66,530
                                                          ----------
                                         Net Savings:        $64,574


Note: the Savings-to-Investment Ratio (SIR) and AIRR computations include differential initial costs, capital replacement costs, and
residual value (if any) as investment costs, per NIST Handbook 135 (Federal and MILCON analyses only).


SIR for Alternative Solar Case Compared to Alternative Basecase

                          P.V. of non-investment savings
                  SIR  = --------------------------------  =  1.97
                           Increased total investment


Adjusted Internal Rate of Return (AIRR) for Alternative Solar Case Compared to Alternative Basecase
(Reinvestment Rate =  4.10%; Study Period = 25 years)

                                   AIRR =  6.96%


Estimated Years to Payback:        Simple Payback occurs in year 10;
                                   Discounted Payback occurs in year 12


                               ENERGY SAVINGS SUMMARY

          Energy            Units    — Average Annual Consumption —       Life-Cycle
           Type                      Basecase  Alternative   Savings        Savings
          ------------    -------   ---------  -----------  --------    -----------

          Electricity         kWh           0        2,362    -2,362        -59,050
          Central Steam      MBtu         940            0       940         23,500
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About the Federal Technology Alerts

The Energy Policy Act of 1992, and subsequent Executive Orders, mandate that energy consumption in the Federal sector be reduced by 30% from 1985 levels by the year 2005. To achieve this goal, the U.S. Department of Energy's Federal Energy Management Program (FEMP) is sponsoring a series of programs to reduce energy consumption at Federal installations nationwide. One of these programs, the New Technology Demonstration Program (NTDP), is tasked to accelerate the introduction of energy-efficient and renewable technologies into the Federal sector and to improve the rate of technology transfer.

As part of this effort FEMP is sponsoring a series of Federal Technology Alerts (FTAs) that provide summary information on candidate energy-saving technologies developed and manufactured in the United States. The technologies featured in the Technology Alerts have already entered the market and have some experience but are not in general use in the Federal sector. Based on their potential for energy, cost, and environmental benefits to the Federal sector, the technologies are considered to be leading candidates for immediate Federal application.

The goal of the Technology Alerts is to improve the rate of technology transfer of new energy-saving technologies within the Federal sector and to provide the right people in the field with accurate, up-to-date information on the new technologies so that they can make educated judgments on whether the technologies are suitable for their Federal sites.

Because the Technology Alerts are cost-effective and timely to produce (compared with awaiting the results of field demonstrations), they meet the short-term need of disseminating information to a target audience in a timeframe that allows the rapid deployment of the technologies—and ultimately the saving of energy in the Federal sector.

The information in the Technology Alerts typically includes a description of the candidate technology; the results of its screening tests; a description of its performance, applications and field experience to date; a list of potential suppliers; and important contact infor-mation. Attached appendixes provide supplemental information and example worksheets on the technology.

FEMP sponsors publication of the Federal Technology Alerts to facilitate information-sharing between manufacturers and government staff. While the technology featured promises significant Federal-sector savings, the Technology Alerts do not constitute FEMP's endorsement of a particular product, as FEMP has not independently verified performance data provided by manufacturers. Nor do the Federal Technology Alerts attempt to chart market activity vis-a-vis the technology featured. Readers should note the publication date on the back cover, and consider the Alert as an accurate picture of the technology and its performance at the time of publication. Product innovations and the entrance of new manufacturers or suppliers should be anticipated since the date of publication. FEMP encourages interested Federal energy and facility managers to contact the manufacturers and other Federal sites directly, and to use the worksheets in the Technology Alerts to aid in their purchasing decisions.

Federal Energy Management Program

The Federal Government is the largest energy consumer in the nation. Annually, in its 500,000 buildings and 8,000 locations worldwide, it uses nearly two quadrillion Btu (quads) of energy, costing over $11 billion. This represents 2.5% of all primary energy consumption in the United States. The Federal Energy Management Program was established in 1974 to provide direction, guidance, and assistance to Federal agencies in planning and implementing energy management programs that will improve the energy efficiency and fuel flexibility of the Federal infrastructure.

Over the years several Federal laws and Executive Orders have shaped FEMP's mission. These include the Energy Policy and Conservation Act of 1975; the National Energy Conservation and Policy Act of 1978; the Federal Energy Management Improvement Act of 1988; and, most recently, Executive Order 12759 in 1991, the National Energy Policy Act of 1992 (EPACT), and Executive Order 12902 in 1994.

FEMP is currently involved in a wide range of energy-assessment activities, including conducting New Technology Demonstrations, to hasten the penetration of energy-efficient technologies into the Federal marketplace.

FEMP
FEDERAL ENERGY MANAGEMENT PROGRAM

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