Technical Assistance

Detailed Case Study

Showering with the Sun at Chickasaw National Recreation Area

Visitors to the Buckhorn Campground at Chickasaw National Recreation Area in Oklahoma can now enjoy hot showers, thanks to unobtrusive, cost-effective solar water heating systems.

Using renewable energy installations in place of conventional energy technologies has emerged as an important strategy to help carry out the mandate to provide services to park visitors without compromising the National Park Service's ability to protect the parks' natural resources.

Mark Golnar, a mechanical engineer with the National Park Service (NPS), describes solar water heating as the "perfect heat source" for the comfort stations at Chickasaw National Recreation Area. "The demand for hot water coincides with the availability of sunlight, which makes solar water heaters the obvious choice," he says. "As a bonus, the solar systems are an environmentally sound and cost-effective way to heat water."

Located about 100 miles (161 km) south of Oklahoma City, Oklahoma, on Lake of the Arbuckles, the facility is used primarily in the summer, when solar energy is abundant. The solar water heating systems supply all the hot water for one large comfort station and two small ones at the Buckhorn Campground. (There are no backup systems.) NPS architect James Crockett worked with Golnar to integrate the systems into the design of the new buildings. These solar water heaters are the first of 25 to be installed during the next several years as the site is developed.

Choosing the system

The decision to use solar water heating at the site was the result of a collaborative effort between the National Renewable Energy Laboratory (NREL) Federal Energy Management Program (FEMP) and Solar Process Heat Program in support of NPS. Chickasaw visitors wanted hot showers, and park personnel wanted an alternative to conventional water heaters. The facility had electricity but no propane, and the cost of heating water with electricity was very high.

NREL/FEMP and NPS personnel considered and rejected several solar water heater configurations before deciding on a system design. They determined that high winter stagnation temperatures would damage fluids in a closed-loop antifreeze system, because the campground is rarely used in the winter and there is little demand for hot water. Draindown and recirculation systems that circulate potable water through the collectors would not work at this site because the hard well water would quickly deposit minerals and obstruct small flow passages. And aesthetic and other site considerations ruled out ground-mounted, tracking parabolic-trough systems.

According to Andy Walker, a member of the NREL/FEMP team, "We concluded that drainback systems, in which the collector heat transfer fluid (in this case water) drains back into the storage tanks when the collector pump turns off, met all the design criteria for this installation. This configuration ensures freeze protection, and even more importantly at Chickasaw, protects the fluid from high stagnation temperatures during the winter months when there is no demand for hot water."

The controller turns the pump on when the collector temperature exceeds the temperature in the storage tank by 20°F (11°C). It turns the pump off when the temperature difference is 4°F (2°C) or less or the temperature in the solar storage tank reaches 180°F (82°C).

Cal Myers/PIX06719

Visitors now enjoy hot showers at Chickasaw National Recreation Area, thanks to solar water heating systems such as the one installed on this large comfort station.

U.S. Department of Energy

Office of Energy Efficiency and Renewable Energy

The solar heat is transferred from the collector water to domestic water by means of a load-side heat exchanger that consists of coils of copper pipe submerged in the storage tank. The water in the storage tank thus acts as a heat sink from which the incoming domestic water draws stored energy in the form of heat. This strategy increases the reliability of the system, reduces maintenance, and eliminates the need for an external heat exchanger and two pumps.

Because this facility is a recreation area, aesthetics were a primary consideration. As a result, all the collectors are installed unobtrusively on south-facing building roofs. The shading effects of hills, trees, and buildings were not a major concern, because the solar systems collect solar energy mostly in the middle of the day and in the summer, when the sun is overhead.

Cal Myers/PIX06720

The solar hot water system on this small comfort station at Chickasaw National Recreation Area supplies all the hot water for the building. There is no backup system.

Performance

The 194 ft^2 (18 m^2) of collectors on each of the small comfort stations' systems provide 9400 kilowatt-hours (kWh) per year. The installations also include 500 gallons (1893 liters) of hot water storage. The system on the large comfort station has 484 ft^2 (45 m^2) of collectors and provides 18,194 kWh per year and 1000 gallons (3785 liters) of hot water storage.

Because the solar systems are the only sources of hot water at the site, it was important to limit the use of hot water and install conservation devices. The size of the heat exchanger limits instantaneous heat transfer from the storage tank, in effect rationing hot water by limiting the rate at which stored energy is delivered to the load. Tempering valves limit hot water delivery by mixing solar-heated water with cold water to achieve a constant temperature of 105°F (41°C). In addition, the load is minimized by very-low-flow showerheads and 1-minute push button timers on the showers.

NREL's FEMP team did hourly simulations to determine how the systems would perform during an average year. The simulations showed that the small systems will only fail to deliver water hotter than 95°F (35°C) for 345 hours of the year (4% of yearly hours), and the large systems for only 579 hours (7% of yearly hours).

Cal Myers, Facility Manager at Chickasaw, is satisfied with the systems' performance. "Last summer (1997) was the first summer the systems were operational, and I didn't hear any complaints from visitors," he says. "I have experience with maintaining and paying the bills for electric water heaters, and I like having hot water without the bills."

Chickasaw Project Details

Project Description: Solar water heating systems on new comfort stations

Owner: National Park Service

Location: Chickasaw National Recreation Area, Oklahoma

Architect: James Crockett, National Park Service

Mechanical Engineer: Mark Golnar, National Park Service

Project Supervisor: Brian Lippert, (303) 969-2234

Solar Contractor: SolarMaster Solar Service Inc., supervised by Odes Castor

Chickasaw Facility Manager: Cal Myers

	Small Comfort Stations	Large Comfort Station
Daily hot water use	660 gal (2498 l)/day	1500 gal (5678 l)/day
Temperature	at least 95°F (35°C)	at least 105°F (41°C)
Collector area	194 ft^2 (18 m^2)	484 ft^2 (45 m^2)
Storage volume	500 gal (1893 l)	1000 gal (3785 l)
Load met by solar	9394 kWh	18,194 kWh
Hours water temperature is less than target	345 hr/yr (95°F [35°C])	579 hr/yr (105°F [41°C])
System efficiency	45%	34%
Annual energy savings	9394 kWh/yr	18,194 kWh/yr
Energy saved during 25 years	234,850 kWh	454,850 kWh

Economics

At Chickasaw, the economics of solar water heating are very attractive. All three systems are cost effective according to the criteria set forth in 10CFR436 of the Code of Federal Regulations (CFR) for Federal facilities. This regulation requires that the life-cycle savings divided by the initial investment (the savings-to-investment ratio) be greater than 1. The Chickasaw systems also fit the definition of cost-effectiveness established in President Clinton's Executive Order 12902 (Energy Efficiency and Water Conservation at Federal Facilities), because they have simple payback periods of fewer than 10 years.

The solar systems at the small comfort stations cost $18,000 each and have a 9-year simple payback, a 6.2% rate of return, and a savings-to-investment ratio of 2.1. The large system cost $24,000, resulting in an 8-year simple payback, a 6.6% rate of return, and a savings-to-investment ratio of 2.4. These figures include the environmental costs of generating electricity based on NPS's assignment of emission costs.

Selling solar

Careful planning and good communication can help ensure the success of renewable energy installations. Solar water heaters are different from conventional water heaters in significant ways. For example, they cost more to buy and are more complex to install and maintain. In addition, maintenance staff are often unfamiliar with the technology and are sometimes resistant to it.

Some Federal managers are also resistant to considering solar water heaters because of past bad experiences. The solar water heating industry experienced failures and bad press in the 1980s, which still linger in some people's minds. And, to make matters worse, it is not uncommon for Federal facilities to have solar water heaters installed on them that have not worked in years—a constant reminder of the deficiencies of early solar equipment.

The good news is that the situation is very different today. After the Federal residential tax credits expired in 1985, many solar companies went out of business. Those that survived continued to refine their products and now sell systems based on mature, reliable, proven technologies. In addition, the Solar Rating and Certification Corporation, a nonprofit national corporation, now develops certification programs and rating standards for solar energy equipment. Most collectors carry 10-year warranties, and systems should last at least 20 years.

In many applications—such as the Chickasaw installations—modern solar water heating systems have economic advantages over conventional water heating systems. A solar water heater's life-cycle costs can be lower than a conventional water heater's, because after the payback period, the solar system continues to produce hot water for only the cost of maintenance.

The big picture

Federal agencies administer more than 31% of the land area in the United States, a large proportion of which is remote and environmentally sensitive. In many of these areas, the need for services is increasing.

In 1991, the NPS identified sustainable design as the cornerstone of an effort to provide services to park visitors without compromising NPS's ability to protect the parks' natural resources. Using renewable energy installations in place of conventional energy technologies has emerged as an important strategy to help carry out this mandate.

Renewable energy technologies are clean, quiet energy sources that help create a more pleasing experience for staff and visitors alike. Solar water heating systems like the ones installed at Chickasaw, for example, consume no fuel, produce no emissions, and—even when economic payoff is small—help agencies fulfill their mandate for responsible stewardship of our national resources.

Leaving a legacy

Protecting the environment is everyone's job, and renewable energy technologies make that possible in tangible and measurable ways. NPS now bases development decisions on life-cycle cost analyses, which include the cost of operating and maintaining installations during their anticipated service life. This is good news for renewable energy technologies, because although they are typically expensive to purchase, they are very competitive on a life-cycle basis.

By using renewable energy technologies to satisfy its mandate to provide services for visitors and protect the park system's natural resources, NPS sets a good example for other Federal agencies and the general public. These technologies offer Federal facility managers the opportunity to comply with Executive Order 12902, meet the cost-effectiveness criteria set forth in 10CFR436 for Federal facilities, and take a step toward leaving their grandchildren a cleaner environment in the bargain.

COST BREAKDOWN	**Small Station**	**Large Station**
Solar System Cost	$18,000	$24,000
Net Present Value of Life-Cycle Cost	$21,300	$28,900
Internal Rate of Return	6.2%	6.6%
Simple Payback Period	9 years	8 years
Discounted Payback Period	10 years	9 years
Savings-to-Investment Ratio	2.1	2.4

NPS Assignment of Emission Costs	**Before 9/97***	**After 9/97***
CO_2	$8/ton ($0.0088/kilogram)	$14/ton ($0.015/kilogram)
SO_2	$0.75/pound ($1.65/kilogram)	$0.85/pound ($1.88/kilogram)
NO_x	$3.40/pound ($7.50/kilogram)	$3.75/pound ($8.33/kilogram)

**The NPS revised its emission costs in September 1997.*

Chickasaw Annual Emissions Cost Estimates

SMALL COMFORT STATIONS (each)	**Avoided Emissions**	**Cost of Avoided Emissions** (Based on revised emissions costs)
CO_2	12 tons (11,000 kilogram)/yr	$151.00
SO_2	68 pounds (31 kilogram)/yr	$52.00
NO_x	83 pounds (38 kilogram)/yr	$281.00
Annual Value of Avoided Emissions		$484.00
LARGE COMFORT STATION		
CO_2	18 tons (16,000 kilograms)/yr	$227.00
SO_2	101 pounds (46 kilograms)/yr	$78.00
NO_x	123 pounds (56 kilograms)/yr	$416.00
Annual Value of Avoided Emissions		$721.00

Note that this analysis deducts the cost of emissions produced by generating the electricity to run the pumps on the solar systems: (CO_2, $17; SO_2, $6; NO_x, $30; total, $53 for each small station; CO_2, $25; SO_2, $8; NO_x, $45; total, $78 for large station).

25-Year Life-Cycle Cost Analysis

Small Comfort Stations (each)	**Basecase**	**Solar System**	**Savings**
INITIAL INVESTMENT			
Capital Requirements	$3,919	$18,000	-$14,081
FUTURE COSTS			
Recurring Costs*	$9,368	$923	$8,445
Energy-Related Costs**	$24,178	$2,371	$21,807
TOTAL PRESENT VALUE	$37,465	$21,294	$16,172
Large Comfort Station (one electric heater for basecase, and two solar water heating arrays for solar system)			
INITIAL INVESTMENT			
Capital Requirements	$4,875	$24,000	-$19,125
FUTURE COSTS			
Recurring Costs*	$13,965	$1,358	$12,607
Energy-Related Costs**	$36,087	$3,540	$32,547
TOTAL PRESENT VALUE	$54,927	$28,898	$26,029

**Recurring costs, including maintenance costs.*

***Energy-related costs, including fuel costs.*

Note that basecase is electric water heaters and that these analyses include National Park Service estimates of costs associated with emissions produced by a utility company in the process of generating electricity.

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This case study is available on the FEMP Web site **(http://www.eren.doe.gov/femp)** and from the FEMP Help Desk (1-800-363-3732).

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