Achieving Results with Renewable Energy in the Federal Government

Heating Water with Solar Energy Costs Less at the Phoenix Federal Correctional Institution

A large solar thermal system installed at the Phoenix Federal Correctional Institution (FCI) in 1998 heats water for the prison and costs less than buying electricity to heat that water. This renewable energy system provides 70% of the facility's annual hot water needs. The Federal Bureau of Prisons did not incur the up-front cost of this system because it was financed through an Energy Savings Performance Contract (ESPC). The ESPC payments are 10% less than the energy savings so that the prison saves an average of $6,700 per year, providing an immediate payback. Boiler maintenance and hot water service call costs for the facility have also been reduced.

The solar hot water system produces up to 50,000 gallons of hot water daily, enough to meet the needs of 1,250 inmates and staff who use the kitchen, shower, and laundry facilities. Because solar energy is cleaner than conventional electric power, the environment benefits as well. Solar water-heating systems add no carbon dioxide or other emissions to the air around them. This renewable energy system offsets an average annual consumption of 1,000 megawatt-hours (MWh) of electricity and the release of nearly 600 tons of CO_2. For comparison, conventional electricity produced in Arizona emits 1,109 pounds of CO_2 per MWh.

The Federal Bureau of Prisons worked with the Department of Energy (DOE) Federal Energy Management Program (FEMP) and the ESPC contractor, Industrial Solar Technology Corporation (IST), to design and install the system. Under the terms of the 20-year ESPC contract, the prison receives 10% of the total energy savings annually (an average of $6,700 per year), and the other 90% goes to amortize the first costs of the system. At the end of the 20-year period, the prison will take over ownership, operation, and maintenance of the solar system and benefit from 100% of the energy savings for the remaining 10 years of the expected service life.

Parabolic trough concentrator modules at the Phoenix Federal Correctional Institution produce up to 50,000 gallons of hot water daily—enough hot water for kitchen, shower, laundry, and sanitation needs for 1,250 inmates and staff.

The solar system includes 17,040 ft^2 of parabolic trough concentrating collectors and a 23,000-gallon storage tank located adjacent to the collectors. Parabolic troughs, like other solar water-heating systems, are most cost effective for facilities with relatively constant hot water needs—places such as prisons, hospitals, and barracks. They heat water onsite using the sun's energy, so the facility can reduce the amount of energy purchased from the local utility for water heating.

Highlights

System Capacity	3.4 million Btu/hr (1,000 kW) of heat at 60% peak system efficiency
Power Production	300 million Btu/month of average delivered heat, offsetting 88,500 kWh/month of electricity consumption to meet 70% of annual need for hot water
Installation Date	1998
Motivation	Replace large domestic hot-water load heated by electricity with good solar resource
Size	120 parabolic trough concentrator modules
Annual savings	$67,000/yr average in electricity costs (90% goes to IST under a 20-year ESPC)

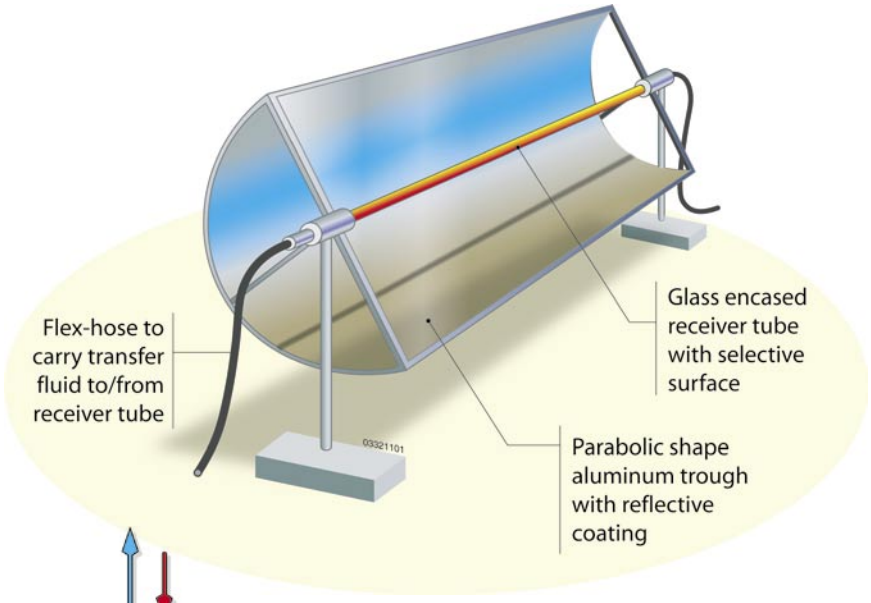


Figure 1: Parabolic trough collector

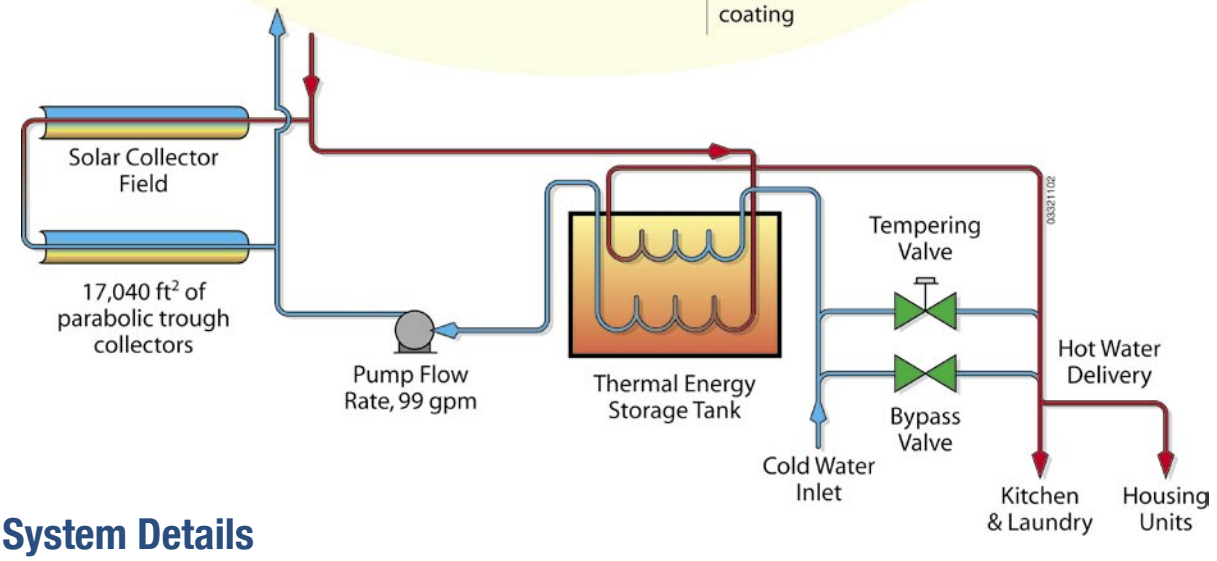


Figure 2: The solar collectors heat a circulating fluid that in turn supplies heat to domestic water storage tanks and end-uses.

System Details

Components	120 parabolic trough collectors totaling 17,040 ft² (1,584 m²) of collector aperture area; propylene glycol solution circulating fluid; a master field controller and four local sun-tracking controllers
Storage	Two steel water tanks with membrane liners, totaling 23,000 gallons (87,055 liters)
Loads	13 million Btu/day (4,000 kWh/day) average to heat 30,000-50,000 gallons of water for laundry, kitchen, and other domestic applications
Supplier/Installer	IST designed, fabricated, installed, and operates the system
Monitoring	Redundant Btu meters measure delivered hot water; plus a datalogger records solar radiation, wind, ambient temperature, flow rates, and fluid and water temperatures
Expected Life	30 years

How the Technology Works

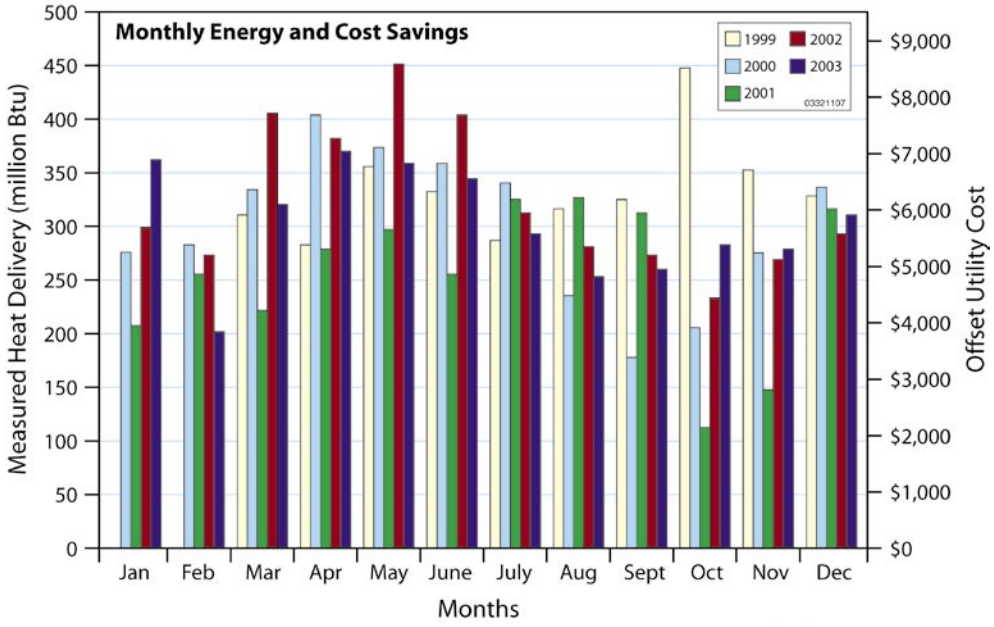
Parabolic trough solar systems convert solar energy to heat. Parabolic trough collectors use mirrored surfaces curved in a linearly extended parabolic shape to concentrate the sun's rays on a pipe running the length of the trough. A mixture of water and antifreeze is pumped through the pipe to pick up the solar energy and then through a heat exchanger to heat potable water. These systems also use single-axis tracking to stay aligned with the sun. Parabolic trough solar systems work well in locations with a high direct-beam solar resource, such as the Southwestern United States. Other solar water heating applications that work well in locations across the country include flat-plate or evacuated-tube collector technology.

Performance

The solar thermal system at Phoenix FCI has been running routinely since March 1999. Under peak solar conditions and when the modules are clean, the solar system delivers up to 3.4 million Btu/hr (1,000 kW) of heat to the energy storage tank at a peak efficiency of 60% of the solar energy incident on the solar collectors. On a sunny day, the solar system delivers up to 50,000 gallons of hot water to the institution, displacing approximately 4,000 kWh of electricity.

On a monthly basis, the system delivers an overall average of 300 million Btu/month, offsetting 89,000 kWh of electricity consumption and an estimated $5,600 of energy costs. The highest months of energy savings, May 2002 and October 1999, coincide with both the best solar resource (the greatest number of clear sunny days) and the highest hot water demand for prison operations. The lowest months of energy savings, such as October 2001, reflect unusually overcast weather, reduced hot water demand, or partial solar system shut down for maintenance or repairs. To optimize operational efficiency, collectors should be cleaned every 2 to 4 months, depending on weather conditions.

Because calculating the electricity rate is complex and variable, an average blended rate for electricity consumption and demand is used here to estimate the utility bill savings ($0.065/kWh). Total annual energy cost savings average $67,000, with 90% going to IST under the ESPC.



Costs

Cost Breakdown for Phoenix FCI Solar Thermal System	
System Cost (total includes: design, hardware, and installation)	$649,000
Per Unit Cost	$38 / ft^2
Equivalent Energy Rate	$12/MBtu $0.04/kWh
Annual O&M Cost (rolled into ESPC)	N/A

Life Cycle Cost Analysis for the Phoenix FCI Solar Thermal System

Study Period: 20 years	Alternative (Electricity utility)	Solar System with Electric Heating Backup
Initial Investment	$ 0	$ 649,000
Recurring Costs (O&M, etc.)	$ 143,419	$ 226,891
Energy Costs	$ 1,528,397	$ 290,465
Total Present Value	$ 1,671,816	$ 1,166,356
Adjusted Internal Rate of Return		6.4 %
Simple Payback Period		8 years
Savings-to-Investment Ratio		1.78

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Project Partners and Funding Sources

IST designed, fabricated, and installed the system under an ESPC with the Federal Bureau of Prisons. The ESPC was developed under a Cooperative Research and Development Agreement with the National Renewable Energy Laboratory. Expertise funded by DOE FEMP facilitated the project from feasibility through to performance measurement and verification. The contract term is 20 years, after which ownership of the solar system will revert to the federal government. ABB Energy Capital provided construction and long-term financing to build the system. IST will operate the solar plant over the life of the contract and currently employs the maintenance services of North Canyon Solar.

IST has invested the capital to install and operate the solar thermal system, charging Phoenix FCI a discounted rate for the energy delivered through an ESPC. The project also benefited from a 10% business energy tax credit for purchase of solar equipment and accelerated depreciation of solar energy property investment. DOE FEMP provided cost sharing in the form of technical assistance for this Site-Specific ESPC project, which was the first time a federal agency used an ESPC for a renewable energy technology.

Federal Renewable Energy Goal

This project is helping the federal government achieve the goal of obtaining 2.5% of electricity from renewable energy by 2005. The Phoenix FCI has one of the largest federal solar thermal systems and one of the earliest renewable energy systems in the U.S. Department of Justice.

O&M and Emissions Benefits

Operational benefits include maintaining temperatures for domestic hot water (in the past the prison frequently ran out of hot water), reducing electricity peak demand for water heating by more than 200 kW, and reducing maintenance and replacement parts for the offset electric boilers. "We save a lot of money on electric water heater elements, maintenance calls, and repairs," says the facilities manager. "[Plus,] the calls we've gotten from the inmates about cold water have basically gone away." Operation and maintenance savings on the existing boilers are in addition to the reduced utility costs. Furthermore, avoided emissions based on Environmental Protection Agency eGRID 2000 factors for Arizona, amount to 589 tons/yr of CO_2, 2,655 lbs/yr of SO_2, and 2,358 lbs/yr of NO_x.

Applications at Other Government Sites

- U.S. Army Fort Sam Houston, San Antonio, Texas: Roof-mounted parabolic troughs provide heat to a pressurized water district-heating loop. Installed June 2003.
- U.S. Army Yuma Proving Ground, Yuma, Arizona: 8,970 million Btu/yr of heat provided for absorption cooling, space heating, and domestic hot water. Installed in 1979 and refurbished in 1986.
- Jefferson County Detention Facility, Golden, Colorado: 1,200 million Btu/yr of heat for domestic hot water. Installed in 1996.
- California Correctional Institution, Tehachapi, California: District heating application. Installed in 1990.

Public Outreach and Awards

- "Million Solar Roofs Initiative Award for 2000," *Save with Solar,* Vol. 3, No. 2., Fall 2000, DOE/ GO-102000-1096.
- "Prisoners in Hot Water," *Arizona Republic,* June 19, 1999.
- "Solar Flares: Technology Hones the Efficiency of Sun-powered Energy Systems," *Mechanical Engineering Power,* July 1999.
- "Performance Contracting of a Large Parabolic Trough System at the Federal Correctional Institution–Phoenix," *Intersociety Energy Conversion Engineering Conference Proceedings; July 24-28, 2000, Las Vegas.* Collection of Technical Papers, 2000; Vol 1.
- "Performance of a Large Parabolic Trough Solar Water Heating System at Phoenix Federal Correctional Institution," *ASME Journal of Solar Energy Engineering,* Vol. 122, No. 4, November 2000.
- "Solar America: A Solar Energy Tour of the United States," CD-ROM, 2001, DOE/GO-102001-1492.

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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