General Services Administration
Public Buildings Service

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HONEYCOMB SOLAR THERMAL COLLECTOR

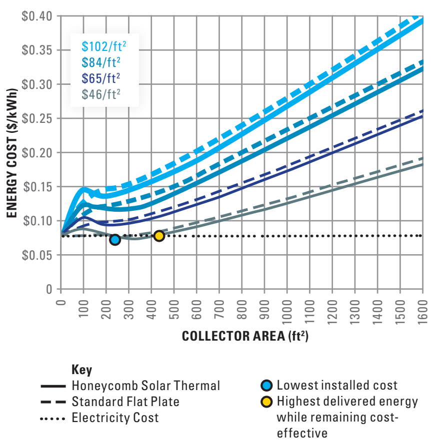
Cost-Effective for Facilities with Electric Water Heaters and Large Consistent Loads

The Energy Independence and Security Act of 2007 (EISA) requires new federal buildings and major renovations to meet 30% of their hot water demand with solar energy, provided it is cost-effective over the life of the system. In response to this mandate, GSA's GPG program commissioned the National Renewable Energy Laboratory (NREL) to assess a unique solar hot water (SHW) collector technology, the Honeycomb Solar Thermal Collector (HSTC). The HSTC uses a honeycomb insulating layer to minimize heat loss, making it particularly effective, manufacturers say, in cold climates, where many GSA facilities are located. The technology was installed at two test-bed locations, the Major General Emmett J. Bean Federal Center in Indianapolis, Indiana, and the GSA Regional Headquarters Building in Auburn, Washington. Researchers found that, for most domestic hot water applications in which mains water is heated by an array of solar collectors and stored in a tank, the HSTC technology was up to 8% more efficient than typical flat-plate collectors. Modeling also demonstrated that for facilities that use electric-resistance domestic hot water heaters, SHW collectors can be cost-effective when responding to loads of at least 500 gallons per weekday.

The GPG program enables GSA to make sound investment decisions in next generation building technologies based on their real world performance.

INTRODUCTION

Optimal System Size for 500-Gallon Load
Seattle, WA (cold/cloudy)



"The most promising application for HSTC is one in which the hot water circulation loop in a large building has heat added to it directly by the solar collectors, rather than using a storage tank. In this type of high-temperature application, where more expensive evacuated tubes have historically been used, HSTC will outperform other flat-plate collectors, particularly in cold climates."

— Jesse Dean
Senior Engineer
National Renewable Energy Laboratory

What Is This Technology?

TRANSPARENT INSULATION ADMITS SOLAR ENERGY, MINIMIZES HEAT LOSS

The Honeycomb Solar Thermal Collector is in some ways similar to other flat-plate solar thermal collectors. It captures sunlight with solar panels and uses the captured energy to heat a fluid (sometimes but not always water) that is then transported from the collector to a storage tank for use in service applications, space heating and cooling, and process heat. It differs from typical flat-plate collectors by incorporating a layer of honeycomb-shaped transparent insulation, which is sandwiched between the glazing and the energy-collecting surface. This honeycomb polymer allows solar energy to enter the HSTC while at the same time minimizing heat loss by suppressing convection. A gap between the insulation and the energy-collecting surface reduces heat loss from conduction that would otherwise occur from the absorber plate through the walls of the honeycomb material to the glass. A proprietary heat pipe serves as an overheat protection device (OPD) to prevent the collector from reaching extremely high temperatures when fluid stagnates, which can happen on clear hot days when loads are small. Though the HSTC OPD has been designed to prevent fluid stagnation, in typical flat-plate collectors persistent high stagnation temperatures can degrade system fluids, resulting, over time, in damage to collector components. The average lifetime of SHW collectors and components is 25 years. HSTC has been manufactured to address issues related to long-term durability but this has not been tested.

What We Did

TWO DIFFERENT SYSTEM DESIGNS TESTED AGAINST MANUFACTURER'S CLAIMS

To test the manufacturer's claim that the HSTC demonstrates high operating efficiencies in cold climates, GSA selected two demonstration sites: the Major General Emmett J. Bean Federal Center in Indianapolis; and the GSA Regional Headquarters Building in Auburn, Washington. Both locations have similar annual average temperatures. Auburn, however, has mild winters, mild summers, and one of the lowest levels of solar resource in the continental U.S., whereas Indianapolis has cold winters, hot summers, and an average solar resource. Though systems at both study sites were designed to heat domestic hot water (DHW), each system accomplished that task differently. The Bean Center has a standard closed-loop system, where a pump circulates a water/propylene glycol mixture through eight collectors and an external heat exchanger. The Auburn site was designed as a recirculation loop, which reheats domestic hot water circulating through four collectors and a solar storage tank. Among NREL's technical objectives was to confirm through field tests that the collector performance was within +/- 10% of the manufacturer's claims. They also analyzed overall efficiency, relative to incumbent technologies, and confirmed that the HSTC's OPD operated as expected. Life-cycle costs and return on investment were also evaluated.

FINDINGS

MEASURED EFFICIENCIES MATCHED MANUFACTURER ESTIMATES With the Bean Center's standard closed-loop system, efficiencies were within 2% of predictions.

FOR MOST DHW, HSTC IS ONLY MODERATELY MORE EFFICIENT THAN TYPICAL FLAT-PLATE In DHW applications where mains water is heated by an array of collectors for temporary storage in a tank, HSTC demonstrated up to 8% greater efficiency than systems using standard flat-plate collectors. Performance did not vary much between hot and cold climates. When used with an alternative system design, in which heat is added to an already-existing hot-water recirculation loop (as was the case in Auburn), HSTC should outperform other flat-plate collectors due to its efficiency at high inlet temperatures. This advantage will be greatest in cold climates. SHW systems without storage tanks require less infrastructure and can be more cost-effective.

HSTC OVERHEATING PROTECTION WORKED The overheating protection device worked as predicted by HSTC's manufacturer, with a maximum stagnation temperature of 152°C (306°F). It is possible that the HSTC OPD might decrease the maintenance costs of an SHW system over its lifetime.

SHW CAN BE COST-EFFECTIVE ACROSS CLIMATE ZONES Modeling showed that HSTC, as well as other solar thermal collectors, can be cost-effective across a range of climate zones, assuming electric reheat, a 500-gallon weekday load, and a $46/ft² installed cost. Less efficient collectors can be more cost-effective if installed costs are substantially lower. On the other hand, because solar collectors themselves are only 20% of the installed cost, a more expensive collector has a relatively small impact on overall costs.

CONSIDER SHW FOR ELECTRIC HOT WATER SYSTEMS WITH LARGE CONSISTENT LOADS The cost-effectiveness of the system in any given location is strongly dependent on the building's hot water load, local utility costs, and installed costs. In general, the larger and more consistent the load being offset, the more cost-effective the system. However, in locations with a high solar resource, such as Phoenix or Denver, a system with a smaller load and higher costs can still be cost-effective. Life-cycle cost, rather than efficiency, should drive system selection.

Modeled Savings for HSTC in Locations with Different Solar Resources

Large loads are critical for positive ROI

City	Hot Water Load (gal/day)	System Unit Cost ($/ft²)	Collector Area (ft²)	Solar Fraction*	Annual Energy Savings (kWh/yr)	Payback (years)	SIR
Seattle, WA cold/cloudy annual solar radiation 5.0 gigajoule/m²/yr	125	$102	88	0.44	3,154	40.0	0.26
	500	$102	175	0.32	8,937	26.8	0.56
	500	$46	175	0.32	8,937	13.0	1.15
Indianapolis, IN cold/partly cloudy annual solar radiation 5.9 gigajoule/m²/yr	125	$102	88	0.51	3,638	29.0	0.42
	500	$102	175	0.38	10,448	19.2	0.81
	500	$46	175	0.38	10,448	9.3	1.68
Denver, CO cold/sunny annual solar radiation 6.8 gigajoule/m²/yr	125	$102	88	0.60	4,291	24.5	0.54
	500	$102	175	0.44	12,343	16.2	0.98
	500	$46	175	0.44	12,343	7.8	2.03
Phoenix, AZ warm/sunny annual solar radiation 8.5 gigajoule/m²/yr	125	$102	88	0.54	2,757	21.4	0.50
	500	$102	175	0.71	13,556	15.0	1.06
	500	$46	175	0.71	13,556	7.3	2.20

* The solar fraction represents the fraction of the total hot water energy load that is displaced by the solar hot water system.

CONCLUSIONS

These Findings are based on the report, "High Performance Flat Plate Solar Thermal Collector Evaluation," which is available from the GPG program website, www.gsa.gov/gpg

For more information, contact GSA's GPG program gpg@gsa.gov

What We Concluded

AMPLE OPPORTUNITY WHERE ELECTRICITY MEETS LARGE DHW LOADS

Solar hot water technology has long been popular internationally but because of relatively high system costs and the low cost of fuels being offset, SHW's commercial success in the U.S. market has been mixed. Given current natural gas prices in the United States, it is generally impossible for an SHW system to be cost-effective over its lifetime. Still, there is ample opportunity for solar thermal technologies to grow and capture more of the DHW market where the DHW load is being met using electricity or other expensive fuels, such as oil or propane. Roughly 25% of commercial building hot water is heated with electricity[1]. GSA has jurisdiction over approximately 1,500 federally owned buildings. A large percentage of those facilities are candidates for rooftop solar installations. In some cases, where water is heated with electricity, SHW systems will make sense financially. In all cases, where SHW is cost-effective, it will help GSA meet EISA requirements.

GUIDELINES FOR DEPLOYMENT

- **Implement Efficiency First** Applicable water conservation and energy efficiency opportunities should be implemented before sizing a solar thermal system.
- **Use Accurate System Design Tools to Optimize Cost Effectiveness** Using the approach outlined in NREL's report to determine system design, a detailed sub-hourly simulation program should be used and the system should be modeled accurately with SRCC-rated solar thermal panel performance data. Life-cycle cost, rather than efficiency, should drive system selection.
- **Use a Trained Solar Hot Water Installer** There are several unique features of SHW systems with which experienced plumbers may not be familiar, such as calculating the required pressure of collector fluid to avoid boiling under stagnation conditions.
- **Require a Backup System** SHW systems almost always require a backup system for cloudy days and times of increased demand.

TARGET LOCATIONS

- **Large, Consistent Weekday Hot Water Loads** The larger the load being offset, the more cost-effective the system.
- **Central Hot Water Systems** Facilities with centralized domestic hot water systems should be targeted for SHW. Facilities with small de-centralized point-of-use domestic hot water systems are not suitable for solar thermal installations.
- **Roof Availability** Facilities with roofs that won't need to be replaced for 20 to 25 years, have sufficient space available to accommodate an SHW system, and won't need expensive structural modifications to carry the increased load.
- **High Solar Resource** Sunny locations are more cost-effective.
- **High Energy Costs** The unit cost of electricity ($/kWh) is seven times higher than natural gas in many locations.

Footnotes

[1]US. Energy Information Administration, (EIA), 2009.

Technology for test-bed measurement and verification provided by Tigi Solar.