# SOLAR WATER HEATING: WHAT'S HOT AND WHAT'S NOT

**Jay Stein**
Senior Engineer
E-Cube, Inc.
Boulder, CO

## ABSTRACT

A handful of electric utilities in the United States now pay incentives to their customers to install solar water heaters or are developing programs to do so. The solar water heater incentives are part of a broader utility demand-side management program designed to reduce system demand during peak summer hours. Solar hot water has the potential to generate significant savings during periods of high solar intensity. For summer peaking utilities, these periods of high solar intensity coincide with the overall system peak.

This paper discusses the basics of analyzing solar water heaters as a demand-side management measure. In addition, four utility solar water heater incentive programs are studied in detail. The paper describes each program and notes the stage of development. Where such information is available, incentive amounts and cost-effectiveness calculations are included.

## INTRODUCTION

While the reader may draw the inference from the paper's title, new technological breakthroughs are not what's hot in solar water heating. To the contrary, solar technology has changed very little in the last ten years. In fact, except for some major material improvements in the eighties, the basic design of solar collectors has changed little from the product manufactured by the Day and Night Company during the period 1909 to 1941 (1).

What is hot today, or more precisely, what is currently of interest to energy conservation decision makers, is which financing mechanisms are appropriate for solar water heating installations. In the past, the burden of investments in solar water heating was carried by the purchasers of such technologies, often with considerable government subsidies in the form of tax credits. It is widely acknowledged that this mechanism for stimulating investments in solar water heaters was a failure.

One major reason for the failure of this mechanism to stimulate investments in solar water heaters is that it was not sufficiently economically attractive to potential purchasers to do so. For the most part, targets of this strategy were homeowners and landlords. These groups, in general, borrow money at high interest rates and require short paybacks on their investments.

From the perspective of renewable energy planners, public electric utilities are well equipped to carry the financial burden of investments in solar water heaters. They already lend and borrow enormous sums of money at low interest rates, understand energy systems and services, and have a business relationship with virtually every home and business in the country. They may also have the motivation to do so, since, in some cases, solar water heaters may be an attractive investment when compared to the cost of fuel, transmission, distribution, new power plant construction, and environmental externalities.

The next section discusses the basics of solar water heaters as a demand-side management measure. The following sections discuss programs at four utilities that either pay incentives for the installation of solar water heaters or are currently developing plans to do so. Each section will describe the utility program, indicate what stage of development it is at, explain what the incentive amounts are, and, where they are available, discuss the program cost-effectiveness calculations.

## SOLAR HOT WATER DSM PROGRAM ANALYSIS

Solar water heaters present special problems when they are analyzed as demand-side management (DSM) measures. The best way to illustrate such problems is to contrast solar water heating with a more conventional DSM measure: commercial lighting fixture retrofit. When lighting fixtures are retrofit, the measure analyst usually knows the



Proceedings of the Eighth Symposium on Improving Building Systems in Hot and Humid Climates, Dallas, TX, May 13-14, 1992

Wattage of the fixtures that are being replaced and when the fixtures are usually turned on. With these two pieces of information it is easy to predict what the savings of the lighting retrofit are (The Wattage of the original fixtures minus the Wattage of the retrofit fixtures.) and when these savings occur (during hours of operation).

Solar water heaters on the other hand derive their savings from harvesting an irregular source, sunlight, and then deliver such savings as hot water is drawn from storage. While it is relatively easy to predict how much energy a two panel solar water heater in Denver would save over the course of an average July, it is difficult to predict how much energy that same water heater will save over the hour ending at 3:00 PM on July 21. As readers familiar with DSM are aware, savings that occur during peak utility periods are most highly valued by utility planners. These are the savings that offset the need to build new power plants and new distribution facilities. Frequently, DSM planners must account for such savings, and they do so by using one or both of the following techniques: 1) monitoring existing or new installations, and 2) using computer software packages to simulate hourly performance.

One such monitoring study conducted by the Florida Solar Energy Center (2) collected data on electrical energy consumption, efficiency, and time-of-day demand from 20 residential solar water heaters in Florida over a two year period. This study concluded that on the average the monitored water heaters exhibited a .7kW demand reduction per heater in the winter, and a .2 kW demand reduction in the summer. Summer demand reduction was lower because the average water heater only contributes .2kW demand to the summer peak load in Florida.

A much smaller study was conducted by The City of Austin Electric Utility (3) on three solar water heaters installed on commercial buildings owned by the city. The heaters were monitored with kilowatt-hour meters and Btu meters, while a computer simulation estimated the electric consumption of an electric water heater without solar back-up. The Austin study concluded that the three solar water heaters exhibited overall demand reductions ranging from .8 to 5.8 kW per system. The demand reduction during the utility's peak demand period, however, was only .3 to .8 kW per system. The authors noted that solar water heater demand reductions are strongly dependent on the timing of the hot water demand. They further concluded that to maximize benefits to the utility, solar water heaters should be installed on buildings that exhibit high water demand during the peak demand period.

An example of the use of hourly simulations to estimate the demand and energy savings of solar water heaters in demand-side management programs is a study conducted by Energy, Mines and Resources Canada (4). This study assessed the performance of residential solar water heaters with either flat plate or vacuum tube collectors by using a combination of WATSUN 12.2 and TRNSYS 12.0 computer simulation models. The outputs of these simulations were used to determine the effects of existing solar heaters on utility peak loads, load factors, and total consumption levels. The researchers then developed computer models for advanced solar water heaters and ran those as well. Through this process researchers were able to identify an advanced system design that had the potential to displace 942 W of capacity requirements, and 4.19 MWh of energy per year.

## MAXIMIZING COST EFFECTIVENESS

As the reader will see in subsequent sections, solar water heaters are only marginally cost-effective as demand-side management measures, so it is important that they be implemented carefully in order to maximize their potential benefits. Following are some suggestions for DSM program designers based on the author's experience:

1. As noted above, the best candidates for solar water heaters are buildings that exhibit high water heating demand during peak utility demand periods. Examples of buildings with such consumption patterns include schools and nursing homes.

2. All cost-effective conservation measures affecting the hot water production and delivery system should be implemented before solar water heating is considered. For example, all the showerheads should be low flow models, pipes close to the solar storage tank and back-up water heater should be insulated, and the back-up water heater should be heavily insulated.

3. Solar hot water should only be implemented to replace electric resistance water heating. Natural gas prices are sufficiently low that solar water heating will not prove to be cost-effective if natural gas is available. Other alternative water heating methods, such as desuperheating and heat pumps, may also be

more economical than active solar and should be evaluated on a local basis.

4. A corollary to marginal cost-effectiveness is long payback periods. Because a long and productive operating life is essential, program design should include an effective operation and maintenance plan.

5. Solar fraction is defined as the portion of the total water heating load supplied by the active solar water heater. For example, if a building required ten million Btu's a year for water heating, and the solar collectors provided five million Btu's, the solar fraction would be 50%.

An interesting characteristic of solar collectors is that they are less efficient at higher solar fractions than lower solar fractions. Higher solar fractions require higher tank temperatures and higher solar collector operating temperatures. Because higher collector operating temperatures lead to higher thermal losses, collector performance is less efficient under these conditions. As a result, the most cost-effective solar water heaters for DSM programs are not necessarily those with high solar fractions. The author's experience is that water heaters with solar fractions close to 50% exhibit the highest net positive benefits from a societal perspective (5).

## CENTRAL VERMONT PUBLIC SERVICE

Central Vermont Public Service Corporation (CVPS) is an investor owned utility based in Rutland, Vermont. Recently, CVPS began implementing a pilot program to determine the "cost effectiveness, savings, applicability, and acceptability" of solar water heating in its service territory (6). The pilot program will take place over one year and will include 16 research sites. CVPS pays the full incremental cost of the solar water heaters--which is expected to be in the range of $3,000 to $3,500. Participants pay only the income tax on the CVPS incentive (7).

Customers are selected to participate in a random manner; however, they must exhibit a level of minimum kWh usage that indicates solar water heating has the potential for successful application. The first contact is made through telemarketing, and a follow-up visit is made to assess solar orientation and installation feasibility. Low income customers are given priority, and CVPS has set a target of 10% for low income participation.

Monitoring is performed with an electric meter and a Btu meter at each site. Monitoring activities start one month before installation of the solar water heater to establish baseline hot water usage, and are expected to continue for at least one year after installation. Participating customers will also be surveyed periodically to test for customer satisfaction and overall impressions of the project.

Although full cost-effectiveness calculations have not been publicly released, it is known from the Public Service Board's response that the pilot program's levelized cost is set at 16¢ per kWh-saved (6). This is high when compared to other DSM opportunities in Vermont. It is hoped, however, that experience with the pilot program will enable the company to reduce costs. Furthermore, the Public Service Board requires CVPS to demonstrate that solar water heating is a cost-effective measure before it will consider approval of a full-scale program.

At the time of writing, in late January 1992, CVPS had completed only one installation, and monitoring was in progress.

## MASSACHUSETTS ELECTRIC

Massachusetts Electric (ME) is an investor owned utility based in Westborough, MA. ME serves just over 900,000 customers in 146 communities scattered around the state. On December 2, 1991, ME released a Request for Proposals (RFP) under the title *Performance Engineering and Verification Service* (8). The RFP details ME's invitation for potential vendors to submit proposals to provide between 100 kW and 2500 kW of verified demand reduction. The target reduction for the entire program is set in the RFP at 10 MW. Payments are limited to $250.00/kW.

The RFP is specifically targeted at non-lighting measures, but also contains a list of additional ineligible measures, which includes gas and oil conservation, lamp removal, manual reset of temperature thermostats, electric to other fuel conversions, power factor corrections, transient surge suppressors, ballast power reducers, cogeneration or self-generation, and reducing customer's production or operating level. Originally, as conceived by the utility, this list also included measures that replaced electric loads with solar energy.



Proceedings of the Eighth Symposium on Improving Building Systems in Hot and Humid Climates, Dallas, TX, May 13-14, 1992

ME is involved in a collaborative conservation program and entered into negotiations with the Massachusetts Public Interest Research Group (MassPIRG) and the state Attorney General's office over including solar water heaters as an eligible measure. After 18 months of negotiations, ME agreed to do so. In an article published in the *Boston Globe* (9), MassPIRG Energy Program Director Alan Nogee was quoted as saying, "If a solar company has the opportunity to bid on, for example, a thousand water heaters, the economies of scale would make the devices economically competitive with other conservation measures."

Mary-Ellen Harn, a spokeswoman for ME, was more reserved in her quote in the same article. She said, "We would be happy to assess any bids for electric savings from solar water heating on the same terms as other conservation measures." The deadline for receipt of bids is February 3, 1992, and the date for the Department of Public Utility's final agreements is set for April 1, 1992. At the time of writing, it is not known whether any solar water heaters will be included in the Performance Engineering program.

## SACRAMENTO MUNICIPAL UTILITY DISTRICT

Sacramento Municipal Utility District (SMUD) has had a solar water heater incentive program in place throughout the 1980's, but there have been few takers for its $1,000 payments in recent years (10). Don Osborn, SMUD's Solar Program Area Head and Senior Solar Specialist attributes such a diminished participation rate to the scant publicity the program has received over the same time period.

SMUD is revamping its solar hot water program and has plans to put an upgraded program in place by April 1, 1992. The new program will be performance based and pay $500, $750, or $1000 for solar heaters that replace electric resistance water heaters. Payment levels will be based on the amount of electric energy offset by the solar heater. All installed systems must be certified by the Solar Rating and Certification Corporation (SRCC) OG-300 guidelines and standards (11). The OG-300 program sets procedures by which packaged solar water heaters are certified on the basis of a review of their design specifications and an analytical evaluation of their components. The OG-300 program also delineates the process by which energy savings for a specific location are calculated. The amount of incentive paid is based on the displaced electric energy predicted by this method.

Mr. Osborn expects that most of the systems installed under the new program will fit into the following categories: direct with draindown freeze protection, direct with recirculation freeze protection, batch, and evacuated tube. SMUD will require special warranty requirements above and beyond those imposed by the OG-300 specification, and will also require that installers be trained and certified by SMUD.

SMUD's official goal is to pay incentives for the installation of 800 heaters over the first year, but Mr. Osborn expects to nearly double that with 1,500 installations. Should the program reach the higher level, and assuming savings of 3,000 kWh/year per heater, the program overall would reach 4,500 MWh in electric savings. Despite having prepared these projections, no cost-effectiveness calculations have been performed for the program as of yet, although Mr. Osborn expects they will be completed soon.

## FLORIDA POWER AND LIGHT

Florida Power and Light Company (FPL) is an investor-owned utility based in Miami, Florida. FPL's solar hot water demand-side management program was initiated in 1982 (12). Residential customers who replace a conventional electric water heater with a solar water heater may receive payments of up to $400 based on the number of people in the household.

Over the period 1982-1990, incentive payments were made for almost 41,000 solar water heater installations. The vast majority of these payments were made during the period 1982 to 1986, reaching a peak of nearly 14,000 incentives paid in 1985. After the conclusion of the federal tax credit on December 31, 1985, the quantity of annual incentive payments dropped rapidly. Over the period 1987 to 1990, approximately 800 to 1,000 payments were made on an annual basis.

When FPL filed its ten-year DSM plan with the Florida Public Service Commission in 1990, it omitted the residential solar water heating incentive program on the basis that the program was not cost-effective. Such a cost-effectiveness estimation was based on an internal FPL study similar to the FSEC study cited above (2). Even though both studies concluded that solar water heaters saved a significant amount of energy on an annual basis, such energy savings do not necessarily equate with cost-effectiveness. Utilities highly value savings coincident with their peak demand times, because such savings defer the construction of new generation, transmission, and distribution facilities. Because both studies also indicated that residential electric water heaters use on the average only .2 kW during FPL's summer peak demand hour (4-5 PM), the economic value of the solar savings to FPL was limited.

Table 1 (12) shows the analysis prepared by FPL based on 1,000 solar water heaters and 1990 dollars. As shown in Table 1, the benefits of the solar water heater program are equal to only 75% of the costs of the program. It should be noted, however, that this analysis does not include environmental externalities.

**1990 Analysis Using Rate Impact Test**
Dollars are in Millions and Present Valued to 1990.

| | |
|---|---|
| **Benefits:** | |
| Avoided Generation Capital | $2.9 |
| Avoided Generation O&M | 0.5 |
| Avoided Transmission and Distribution Capital | 0.3 |
| Avoided Transmission and Distribution O&M | 0.1 |
| Net Avoided Fuel | 0.4 |
| **Total Benefits** | **$4.2** |
| Costs: | |
| Incentive Payments | $1.3 |
| Program Administrative Costs | 0.5 |
| Lost Revenues | 3.8 |
| **Total Costs** | **$5.6** |

**Benefit-to-Cost Ratio = $4.2/$5.6 = .75**

**Table 1: Cost-Effectiveness of Solar Water Heating Incentives on FPL's System**

Soon after the commission approved FPL's DSM plan without a residential solar incentive program, the Florida Solar Energy Industries Association (FLASEIA) petitioned for a re-examination. FPL entered into a joint review with both FLASEIA and the Florida Solar Energy Center. The joint review team reviewed FPL's calculations, employed cost-effectiveness tests that incorporated a broader perspective, and explored alternative financial scenarios. At the end of the joint review the parties were still unable to demonstrate that the solar water heater incentive payments were cost-effective.

In any event, FPL decided to continue the solar water heater incentive payments on the basis that a conventional cost-effectiveness analysis does not account for all the benefits of solar water heating. One such "difficult to quantify" benefit noted by FPL's Dr. Sim in Reference (12) is the potential of increased fuel diversity that can be gained from continued development of solar water heaters. FPL filed a new plan with the Commission in December, 1990, and the solar water heating incentive program continues uninterrupted.

## DISCUSSION

While the above case studies are not meant to be all inclusive, there is sufficient information to draw several impressions:

1. The solar hot water incentive programs at three of the four utilities, the exception being Florida Power and Light, are in their early stages. While it is too soon to determine their successes, failures, or overall value as DSM programs, it is clear that such programs represent a trend worth monitoring.

2. In three out of four cases, the exception being the program at Sacramento Municipal Utility District, outside advocacy groups played a role in the development of the program.

3. The cost-effectiveness of residential solar water heaters as a DSM measure can only be characterized as marginal. In the case of FPL, calculations indicated the program was not cost effective. However, the FPL analysis did not include "difficult to quantify" benefits that may be attributed to solar water heating in a more comprehensive analysis. In any event, three of the four utilities see value in developing their capability to deliver solar water heater DSM measures.

4. Little work has been done to explore the cost effectiveness of commercial solar water heaters. Such measures may prove to be far more cost-effective than residential heaters, as they may be selected for high levels of hot water consumption during peak utility periods. It is during such time periods that utilities most highly value electric savings.

## REFERENCES

1. Butti, K. and Perlin, J. 1980. A Golden Thread. Palo Alto, California: Cheshire Books.

2. Merrigan, T. and Parker, D. 1990. "Electrical Use, Efficiency, and Peak Demand of Electric Resistance, Heat Pump, Desuperheater, and Solar Hot Water Systems." Proceedings of ACEEE 1990 Summer Study on Energy Efficiency in Buildings. Washington, D.C.: American Council For an Energy-Efficient Economy.

3. Ewert, M., Hoffner, J.E., Panico, D.. May 1991. "A Case Study of Electric Utility Demand Reduction With Commercial Solar Water Heaters." Journal of Solar Energy Engineering, Vol 113. Fairfield, NJ: American Society of Mechanical Engineers.

4. McClenahan, D. August, 1991. Supply and Demand Side Benefits of Solar Domestic Hot Water Systems: Phase I. Ottawa, Ont.: Energy, Mines and Resources Canada.

5. Stein, J. June, 1992. "A Study to Determine the Cost-Effectiveness of Active Solar Water Heating as a Demand-Side Management Measure." Proceedings of the National Solar Energy conference. Boulder, CO: American Solar Energy Society.

6. Central Vermont Public Service Corporation. September 28, 1990. Docket No. 5270-CV-3: Residential Solar Water Heating Project. Montpelier, Vermont: State of Vermont Public Service Board.

7. Private telephone conversation with Nick Sinos of Central Vermont Public Service, January 10, 1992.

8. Request for Proposals For Performance Engineering and Verification Service. 1991. Westborough, MA: Massachusetts Electric Company.

9. Gelbspan, R. September, 1991. "Mass. Electric May Offer Solar Water Heating." Boston Globe. Boston, Massachusetts.

10. Private telephone conversation with Don Osborn of Sacramento Municipal Utility District, Solar Program Area Head and Senior Solar Specialist, January 17, 1992.

11. SRCC Document OG-300-91. 1991. Operating Guidelines and Minimum Standards for Certifying. Washington, DC: Solar Rating and Certification Corporation.

12. Sim, S.R. September/October 1991. "Residential Solar DSM Programs." Solar Today. Boulder, CO: American Solar Energy Society.