The American Council for an Energy-Efficient Economy
Emerging Technologies Report

Solar Water Heaters, *aka* ***Solar-Assisted Water Heaters*** April, 2007

Summary

Definition	Water heating systems that primarily use solar thermal energy, augmented by existing/basecase electric back-up storage water heating systems				
Basecase	*Electric:* Residential 50-gallon storage water heater with energy factor (EF) of 0.88 *Gas:* Residential 40-gallon storage water heater with EF of 0.56 (average of pre- and post-2004 federal minimum-efficiency standards)				
New Measure:	Complete solar (assisted) residential water heating system (freeze-protected and not), including collectors, pumps, and controllers	Percent Savings by App.	2020 Savings TBtu (Source)	2020 Cost of Saved Energy	Success Rating (1-5)
	Electric base system	58%	22	$0.15 / kWh	4
	Gas base system	58%	636	$26.00 / MMBtu	4

Background and Description

Almost all single-family and small multi-family housing units in the United States use free-standing storage water heaters to provide “service hot water” for cooking, bathing, cleaning, and related functions, accounting for about 13% of the energy used in the residential sector (DOE 2005). High-efficiency alternatives to conventional storage water heaters, including condensing storage, tankless, solar-assisted, and electric heat pumps, have limited market shares in the U.S. today. Currently, the market for solar water heating (SWH) systems, excluding pool heating, is in the range of 6,000 units/year, with more than half of these sales in Hawaii (DOE 2005).

In general, SWH systems are mounted on a south-facing roof, or adjacent to the house at ground level. In either case, it is generally remote from the back-up and supplementary storage water heater and its tank. This distance, or the amount of finished space the loop must traverse in a retrofit installation, impacts the method and cost of installation. The most fundamental distinction is between systems that must resist freezing (closed-loop systems), and those located in “sun belt” (see Figure 1) climates with very rare freezing severe enough to threaten the integrity of the system (open-loop systems). Because closed-loop systems require either drain-back provisions or a separate freeze-protected loop to indirectly heat water in the storage tank, they generally have active components (pumps) and are more complex. In addition to system configuration, a number of collector technologies are used in existing systems, including flat plate collectors, several types of evacuated-tube collectors, integral, and batch collectors (FSEC undated).

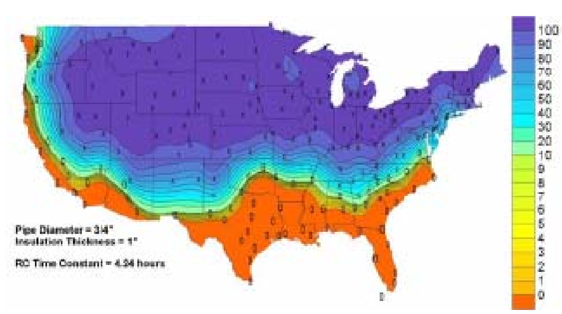

Figure 1. Probability of at Least One Pipe Freeze in 20 Years (assuming house is always occupied)
Source: DOE 2005

Data Summary

Basecase: Residential 50-gallon **electric** water heater with EF of 0.88 (average of pre- and post-2004 federal minimum)

New Measure: Complete solar (assisted) residential water heating system (freeze-protected and not), including collectors, pumps, and controllers

Application and Status			
Market Sector(s)	**Application(s)**	**End Use(s)**	**Fuel Type(s)**
Residential	New Construction Retrofit	Water Heating	Electricity
Market Segment	**National/Regional**	**Region(s)**	**State(s)**
None	National		
Current Status	**Date of Commercialization**	***Notes***	
Commercialized	1975	Arbitrary year. Technology has been available for over 3 decades.	
Market Players/Manufacturers	**Life**		
- Florida Solar Energy Center - Solar Rating and Certification Corporation	14	DOE (2001)	

Basecase Information			***Notes (Source)***
Efficiency	0.88	EF	Average of pre- and post-2004 federal regulation
Electric Use	3459	kWh/yr	DOE (2001)
Summer Peak Demand	0.6	kW	ACEEE estimates 15% coincidence at 4,000 watts max draw
Winter Peak Demand	2	kW	ACEEE estimates 50% coincidence at 4,000 watts max draw
Gas/Fuel Use	0	MMBtu/yr	
New Measure Information			***Notes (Source)***
Efficiency	N/A		
Electric Use	1459	kWh/yr	Fairey (2007); equivalent to 6w continuous draw at 8760 hours/year
Summer Peak Demand	0	kW	Fully sun-powered at summer peak
Winter Peak Demand	2	kW	No solar contribution at winter peak
Gas/Fuel Use	0	MMBtu/yr	
Savings Information			***Notes (Source)***
Electric Savings	2000	kWh/yr	
Summer Peak Demand Savings	0.6	kW	
Winter Peak Demand Savings	0	kW	
Gas/Fuel Savings	0	MMBtu/yr	
Percent Savings	58	%	
Feasible Applications (%)	24	%	We estimate technology applies to 80% of single-family and 2-4-unit multi-family households (78%) in all U.S. climate zones (EIA 2003). 38% electric.
Industrial Savings Potential (>25%)	NO		
2020 Savings Potential	**2,086**	**GWH**	
2020 Savings Potential (Source)	**22**	**TBtu**	
Cost of Saved Energy	**$0.15**	**$/Kwh**	
Cost Information			***Notes (Source)***
Incremental Cost	$3000	2006 $	Reflects 40% reduction goal from current average install cost of $4850 (see Table 1). Our figure assumes 3-4 person household (2 collector panels), freeze-protected system with basic installation. Based on research and a survey of manufacturers across U.S.
Other Costs / (Savings)	0	$/yr	

Success Factors			
Market Barriers	**Non-Energy Benefits**	**Current Promotional Activity**	**Next Steps**
- High first cost - Intermittent use - Public awareness	- Visible “green” statement	- Utility incentives (scattered) - Federal tax credits (2006-2008)	- Field demonstrations - Case studies - ENERGY STAR incorporation - Sustained incentive programs - Mass procurement - Whole system rating
Priority (1-5)	**Likelihood of Success (1-5)**	**Success Rationale**	
4	4	Energy savings can be enormous, but will require large economies of scale *and* changes in trades’ responsibilities and coordination for success.	
Data Quality Assessment (A-D)	**Data Explanation**		
B	We have today’s sales prices but little feel for future declines.		

Data Summary

Basecase: Residential 40-gallon **gas** water heater with EF of 0.56 (average of pre- and post-2004 federal minimum)

New Measure: Complete solar (assisted) residential water heating system (freeze-protected and not), including collectors, pumps, and controllers

Application and Status			
Market Sector(s)	**Application(s)**	**End Use(s)**	**Fuel Type(s)**
Residential	New Construction Retrofit	Water Heating	Gas
Market Segment	**National/Regional**	**Region(s)**	**State(s)**
None	National		
Current Status	**Date of Commercialization**	***Notes***	
Commercialized	1975	Arbitrary year. Technology has been available for over 3 decades.	
Market Players/Manufacturers	**Life**		
- Florida Solar Energy Center - Solar Rating and Certification Corporation	14	DOE (2001)	

Basecase Information			***Notes (Source)***
Efficiency	0.56	EF	Average of pre- and post-2004 federal regulation
Electric Use	0	kWh/yr	
Summer Peak Demand	0	kW	
Winter Peak Demand	0	kW	
Gas/Fuel Use	19.5	MMBtu/yr	Hunt (2007)
New Measure Information			***Notes (Source)***
Efficiency	N/A		
Electric Use	0	kWh/yr	
Summer Peak Demand	0	kW	
Winter Peak Demand	0	kW	
Gas/Fuel Use	8.19	MMBtu/yr	
Savings Information			***Notes (Source)***
Electric Savings	0	kWh/yr	
Summer Peak Demand Savings	0	kW	
Winter Peak Demand Savings	0	kW	
Gas/Fuel Savings	11.3	MMBtu/yr	
Percent Savings	58	%	
Feasible Applications (%)	34	%	We estimate technology applies to 80% of single-family and 2-4-unit multi-family households (78%) in all U.S. climate zones (EIA 2003). 55% gas.
Industrial Savings Potential (>25%)	NO		
2020 Savings Potential (Source)	**636**	**TBtu**	
Cost of Saved Energy	**$26.00**	**$MMBtu**	
Cost Information			***Notes (Source)***
Incremental Cost	$3000	2006 $	Reflects 40% reduction goal from current average install cost of $4850 (see Table 1). Our figure assumes 3-4 person household (2 collector panels), freeze-protected system with basic installation. Based on research and a survey of manufacturers across U.S.
Other Costs / (Savings)	0	$/yr	

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Market Barriers	**Non-Energy Benefits**	**Current Promotional Activity**	**Next Steps**
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Priority (1-5)	**Likelihood of Success (1-5)**	**Success Rationale**	
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Current Status of Measure

Currently, the market for SWH systems, excluding pool heating, is in the range of 6,000 units/year, with more than half of these sales in Hawaii (DOE 2005).This number compares with annual sales of about 100,000 to 300,000 for tankless water heaters, and almost 10,000,000 conventional gas and electric storage water heaters.

The technology is not currently regulated under federal water heaters efficiency requirements, although this is likely to change in the next rulemaking (DOE 2007). In general, SHW systems have not been a priority for many organizations seeking to promote energy conservation. Indeed, the principal solar trade association, SEIA, gives this set of technologies only passing reference. Groups that have been more active in promoting, testing, and/or certifying solar water heating technologies include the Florida Solar Energy Center (FSEC) and the Solar Rating and Certification Corporation (SRCC). ASHRAE also provides a Method of Test (ASHRAE 1987).

SWH technology is relatively simple and the materials and manufacturing involved have been well-understood for decades. Historically, market penetration and promotional activity have depended primarily on financial incentives that lower the upfront cost burden to consumers. The federal Energy Policy Act of 2005 established a substantial federal tax credit of 30% of the cost of a new system up to $2,000. This credit has been extended through 2008. We did not find rebates in California for SWH systems (even though California as well as several states offer rebates or other incentives for photovoltaic systems). However, the California Tax Code provides an exemption of “solar property” installation from property tax increases, for a period to end in the 2008-2009 fiscal year. Without this exclusion, capital-intensive solar systems would suffer an additional property tax burden.

Savings Potential and Cost-Effectiveness

Fairey (2007) noted that a well-designed solar water heating system is likely to save about 2,000 kwh/yr almost anywhere in the United States. This is somewhat counterintuitive. Although there is more solar radiation in the South, it has more value in the North, where the temperature of the incoming water is much lower, so the required temperature “lift” is much higher.

System cost varies more widely. Main cost drivers for whole-system installations include open vs. closed loop (explained above) and new construction vs. retrofit, equipment costs, and economies of scale, explained below. When varying our analysis by installed cost based on research and discussion with manufacturers, we find costs of saved energy in the range of 12–29¢/kWh. Stated cost reduction goals for 2020 from the DOE Water Heating Roadmap (DOE 2005) fall on the low end of this range based on ACEEE analysis (see Table 1).

Table 1. Impact of Roadmap Cost Reduction Goals

	ACEEE Estimates with 40% 2020 Cost Reduction	
	2007	2020
Installed System Cost	$ 4,850	$ 3,000
$/kWh saved	$ 0.24	$ 0.14

Assumes 14-year life; 4.53% interest rate, and 2,000 kWh/year saved.
Source: DOE (2005)

New construction vs. retrofit. In theory, installing a solar water heater at time of construction can be much less expensive than retrofitting because wall finishes don’t have to be disturbed to run piping and wiring. Nonetheless, in practice the costs are often comparable. In certain parts of the country, manufacturers quoted similar pricing for new construction due to multiple visits during the construction phase. According to FSEC (Kettles 2007), common trade practices raise the cost of new installations.

Equipment costs. System costs today are high and vary depending primarily on size. (Our analysis averages cost estimates for 4-person and 6-person household installations.) Compared to size increases, freeze-protection does not incur significant incremental costs. ACEEE finds that current closed systems cost roughly $2,500–4,000 for equipment. Open systems are in the range of $2,600 (DOE 2005; discussions with manufacturers).

Economies of scale. DOE (2005) suggested that designs for larger-scale manufacturing can help reduce prices by 25–50%, with cost of saved energy targets of 4–6¢/kWh for open or passive systems (25–50% cost reduction), and 6¢/kWh for active or closed systems (DOE 2005). Certainly, for collector technologies such as vacuum panel and polymer collectors, very large cost reductions should be anticipated with large-scale production, which will reduce average installed system prices. Muller and Sachs (1993) argued by analogy that a solar water heating system, without the back-up water heater, should cost no more than a refrigerator in mass production: The product mass is similar, and if anything the product complexity is greater for the refrigerator. The biggest difference (in a mass production environment) is that the labor component for installation is much higher for the solar water heating system.

Market Barriers

SWH systems by nature are generally visible to the community, whether ground- or roof-mounted. In some cases, community associations or jurisdictions have attempted to limit or prohibit both solar thermal and photovoltaic systems mounted where they may be visible. To balance aesthetic and energy concerns, California Civil Code 714 prescribes and limits allowable prescriptions. It includes the concept and definition of a "solar easement" (Section 801.5): that is, the conditions under which a property owner can have access to sunlight without blockage by neighbors.

Other barriers to solar water systems are common to other emerging technologies: awareness; high purchase prices; historical reliability problems (real and perceived); lack of an ENERGY STAR program that would provide credibility; and very rare support from incentive programs (Roadmap 2005, p. 5, 19). In addition, solar water heaters bring the unique limitation that it is hard to actually measure the avoided purchased energy, that is, the contribution of the solar heater itself.

Next Steps

ACEEE recommends that utilities and public benefit programs immediately start activities to increase the understanding of the potential of these technologies. In particular, we recommend undertaking well-structured field demonstrations to develop case studies for climate-appropriate systems. This is probably the best way to generate actual data and provide structured feedback to manufacturers on installation and performance questions.

We strongly recommend that the ENERGY STAR New Homes program, and all other utility and public benefit programs, require rough-in piping (and wiring) for participation. This will move the task from the solar contractor to the construction plumber, greatly reducing costs. It will also establish a class of identifiable houses for early marketing of solar water heaters.

Serious market transformation, whether led by tax credits or other incentives, will require sustained programs, perhaps for as long as a decade. In addition to current types of incentives and credits, it may be worth considering mass procurement—for example, for government housing and housing subsidized or guaranteed by federal funds (such as FHA loans). The goal would be to combine several elements: multi-year bids, for a minimum of 5–7 years; substantial annual increases in number procured (perhaps 20%); annual *decreases* in cost per unit, at a smaller rate; and performance guarantees. This can lead to cost-effectiveness for sponsors, and enables industry to finance expansion to mass production on the strength of the procurement contracts.

Solar water heaters can be rated in two ways: by the performance of the collector (SRCC OG-100; RM-1) and by performance of the complete water heating system (SRCC OG-300). ACEEE recommends that incentive programs focus on system standards, requiring OG-300 or equivalent, and also require certified collectors.

Key Assumptions Used in Analysis

Our cost estimates are based on a small survey of manufacturers, and inferences are drawn from the *DOE Technology Roadmap* (DOE 2005). We assume 40% system price reductions for 2020, interpolating between the *Roadmap* (DOE 2005) goals of 25–50%. This will require aggressive public policy and market transformation actions.

Average Price of Electricity	$0.083/kWh
Percent New Res. Construction in 2020 (DOE 2005)	14.8%
Average Price of Natural Gas	$10.16/MMBtu
Projected 2020 End Use Electricity Consumption (EIA 2006)	0.39 quads
Real Discount Rate	4.53%
Projected 2020 End Use Gas Consumption (EIA 2006)	1.25 quads
Heat Rate	10.42 kBtu/kWh

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