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Efficiency and Solar Water Heating: Untapped Potential

by Brady Bancroft

Solar water heating is more than just a dream for an environmentally sound future. If combined with increased efficiency of the entire water heating process, it is practical today.

Virtually all of the electricity currently used for heating water can be saved through a combination of technologies and strategies that deliver the desired service, and at a cost lower than the typical residential electric resistance water heating system. This is the surprising conclusion of the Rocky Mountain Institute's comprehensive report on water heating, part of its Competitek series of reports on electric energy efficiency.[1]

In fact, the majority of residential water heating energy (61–65%) can be saved through a wide variety of efficiency improvements at an average cost of saved energy (CSE)[2] of less than 0.7¢/kWh. The remaining 35–39% savings can be achieved through a number of alternative water heating strategies, including solar. The average CSE for these alternative water heating systems was found to be about 2–4¢/kWh. Although this is higher than the 0.7¢ for the efficiency measures, it is considerably lower than the U.S. average residential rate of 8¢/kWh, which is the cost of heating water with a standard electric resistance storage tank system.[3]

Saving virtually all of the electricity used for water heating is possible for several reasons:

- A number of **water-efficient end-use devices** can deliver the desired hot-water service (namely clothes washing, dishwashing, showering, etc) while using substantially less hot water than their conventional, less-efficient, counterparts.

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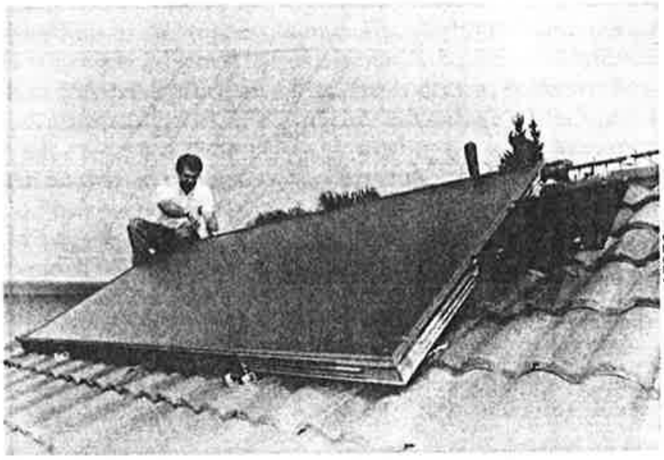


Robin Flynn, courtesy of FSEC

Jim Huggins of the Florida Solar Energy Center inspects a flat-plate solar collector. The black panel visible on the right side of the photo is a photovoltaic array that powers a direct current pump to drive the unit.

- Most hot water systems are plagued by a number of energy loss mechanisms. Often 20–30% of the energy that goes into heating the water is lost before it is ever used. Much of this loss is preventable through a variety of **loss reduction techniques.**
- Perhaps most importantly, electric energy used for water heating can be saved by deploying a variety of **water heating system alternatives.** Whereas tasks such as operating motors or lights need electricity to operate, water heating does not necessarily require electricity. In fact, using its special qualities to obtain the low-grade heat necessary for heating water is generally an inappropriate use of electricity. In most cases the electric resistance storage tank is the *worst* option for heating water, while the best may well be solar. Before solar water heating is practical and cost-effective, however, the water heating load must be reduced through efficiency measures.

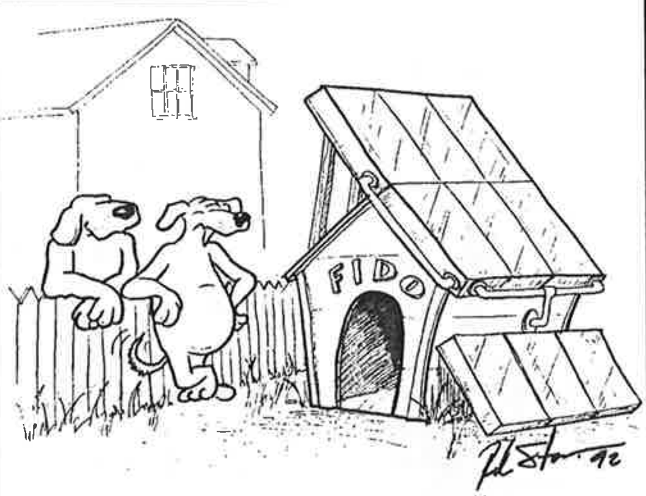
Water-Efficient End-Use Devices

Implementation of water-efficient end-use technologies is the first step to reducing home hot water energy. Average hot water use breaks down as follows:

- 49% for bathing, of which roughly three-fourths is for showers,

- 26% for clothes washing,
- 14% for dishwashing, and
- 11% for sinks.

This breakdown is helpful in pinpointing the potential savings from each end use. If showerhead flow rate is reduced from a nominal 4.0 gal/min to 1.4 gal/min, 65% of shower hot water can be saved. A 20-year lifetime water-efficient showerhead is a great investment with a CSE of only 0.11¢/kWh.



Let me tell you, it sure has made a difference in the way I look at baths!

One-quarter of the hot water delivered to washing machines can be saved by eliminating the warm water rinse. (The 1994 Federal appliance standards will mandate this feature.) Full use of horizontal-axis machines instead of vertical-axis machines would save 50–65% of washing machine hot water at a zero marginal cost, while switching to cold water detergents could save all the hot water energy at zero cost.

About 22% of dishwashing hot water can be saved through a number of efficiency improvements in the dishwasher's food filters, spray arm geometry, fill control, sump geometry, and motor, combined with reduced inlet water temperatures and booster heater improvements. Assuming a 12.6-year lifetime, we found that the cost of saved energy for these improvements is 1.08¢/kWh.

Water-efficient faucet aerators, which last 20 years, can save half of the sink hot water at a CSE of between 0.08¢ and 0.38¢/kWh. When these aerators are combined with the new ultrasonic on/off sink controls, the estimated savings rise to 68% at a combined CSE of 4.26¢/kWh.

Reducing Losses

Standby losses account for 10–20% of the total energy "use" in a typical residential hot water system. To minimize standby losses:

- Increase the storage-tank-wall insulation.
- Decrease the tank water temperature by lowering the thermostat to about 120°F.
- Add anti-convection valves or 360°-loop heat traps on both the tank's inlet and outlet pipes.
- Insulate the first few feet of both the inlet and outlet pipes to cut conductive heat loss from the tank through the metal pipes.
- Insulate around other tank penetrations including the thermostat and the bottom drain valve. A new device called a "pop cozy" insulates the pressure-temperature relief valve without touching it, allowing safe insulation of even that orifice. [*Editor's note*: Make sure not to insulate the pressure relief valve with the water heater blanket, for safety reasons, or the air intake of gas water heaters, to allow sufficient oxygen to the flame.]

Distribution losses, which account for 5–15% of the total hot water energy use, can be reduced by two-thirds for less than 0.7¢/kWh with the following measures:

- Insulate all of the hot water pipe runs to slow the rate of heat loss from the hot water in the pipes.
- Reduce the temperature of the hot water, thus reducing the temperature difference between the pipes and the ambient air.
- Locate the hot water tank closer to the end-use devices to minimize the length of the pipe runs and thus the amount of hot water stranded in the pipes.
- Do not turn on the hot water tap for draws so small that hot water will not even have time to reach the faucet. (Children will often do this.)
- Use smaller-diameter pipes as permitted by water-efficient end-use devices (subject to local codes).

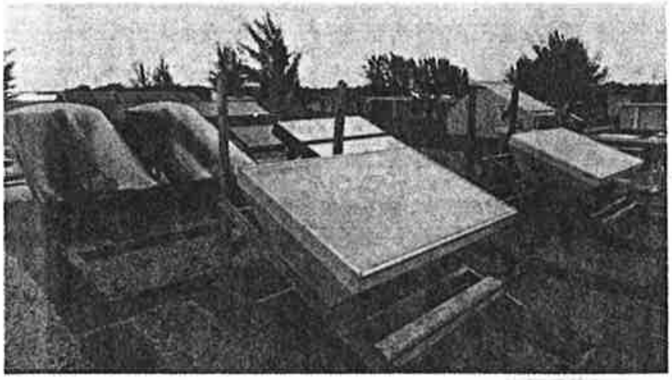
The Solar Alternative

Once hot water demand has been trimmed by efficiency measures such as these, solar becomes an extremely attractive and cost-effective way to provide the remaining hot water.

Solar water heating offers the best long-run solution to the permanent reduction and elimination of electricity used for heating water. These statements may come as a surprise to those who have experience with solar hot water systems installed in the late 1970s and early 1980s. That was a time of large tax credits, unscrupulous salespeople, a general lack of understanding of how to best implement this technology, and many slapdash systems that were poorly designed and never worked well. To make matters worse, when the tax credits disappeared, so did many solar businesses, leaving thousands of "orphan systems" that were doomed to break down for lack of proper maintenance. The net result was a lot of irate solar system owners and a black eye for the entire solar industry.

Revisiting the solar option with a fresh perspective reveals a small but stable industry. A variety of well-made solar water heating products are currently available through a solar industry made up of knowledgeable people who can size, install, and properly maintain a solar hot water system.

The **batch water heater**, one of the simplest solar designs, is still being made by at least two companies in the United



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Batch collectors, such as these undergoing testing, are an efficient solution to the water heating needs of an increasing number of schools and businesses.

States: Alternative Systems (Tucson, Ariz.) and Sunshine Systems (Grass Valley, Calif.). This design continues to be popular due to its low cost and high reliability. (A two-collector batch system can be purchased for as little as $1,200 uninstalled. A do-it-yourselfer can still make one of these collectors from no more than $100–200 worth of materials.) A $1,200 system plus $100 for extra plumbing and another $300 for installation would, over its lifetime, deliver hot water at a CSE of less than 3¢/kWh. This solar water heater design is generally underutilized because of the perception that it is not very efficient. Although it is true that some other designs have higher efficiencies, in many locations this should not be a determining factor. For example, in areas with lots of sunshine, the differences in collector efficiencies become less critical. This is especially true in mild climates. A good general rule is to install the *simplest* system that will do the job.

Another relatively simple passive design is the **thermosiphon system**, which has seen some design refinements that have made units more efficient and more versatile. Many of the new systems have improved heat exchange designs and better insulated storage tanks. One such system, which holds some promise (although as yet unproven in the United States), has a collector with flexible riser tubes that expand and contract during freezing and thawing cycles. This enables the system to run water directly through the collector, which will help maximize the system's efficiency while offering freeze protection. This product, made by ASAHI Solar Corp., Oita, Japan, is not available in the United States yet.

Some more advanced passive designs are more complicated and more expensive. However, they tend to have high efficiencies while still avoiding "parasitic" energy use (input energy required to make the system work, e.g. pumps). One design uses a **phase-change fluid** moving up through a riser placed inside an evacuated tube. This design works well but can be difficult or expensive to repair if the tubes break.

One of the most popular **advanced passive designs** to enter the market in recent years is the Copper Cricket, made by Sage Advance Corp., in Eugene, Ore. It uses a fluid action similar to percolating coffee to circulate the hot fluid to the heat exchange. This highly efficient design works especially well in less optimal solar climates because it is able to capture and transfer energy at collector temperatures as low as 65°F. Another advantage is that the collector side is a closed loop requiring little maintenance. An analysis of this system in different locations from Boston to Phoenix revealed that it delivered hot water in the range of 5.4¢–9.4¢/kWh. This is within the range of normal U.S. residential electric rates but without the problems associated with fossil fuel and nuclear power plants.

Sage Advance

The "Copper Cricket" solar water heater works on a "percolator" principle. Hot fluids from the collector portion percolate into the heat exchanger without need of a pump.

Active solar systems can still be worthwhile, especially in larger scale (for instance multifamily) applications. In larger systems, the energy output of the system increases faster than the costs of additional collectors, pumps, controllers, and installation labor. Because the quality of the components is higher than it was a decade ago, a well-maintained active solar system is an increasingly reliable, cost-effective water heating option.

There are two main barriers to the widespread use of solar water heating. The first is that the individual is expected to pay the entire capital cost up front and realize the

Robin Flynn, courtesy of FSEC

Carter Quillen examines an evacuated tube solar system at a Florida Solar Energy Center test facility. This type of system is one of the most efficient in existence, but replacement of broken tubes is costly.

savings over the life of the system. Yet this same consumer never pays the cost of an electric generating plant up front. This difference in energy payment mechanisms makes solar water heating appear to cost more, even though over the life of the system it is usually a less expensive option.

An additional barrier is that the *true* cost of energy is not reflected in its *apparent* cost. True costs include government subsidies, tax breaks, environmental costs, and health effects. When these hidden costs are incorporated into the cost of each energy option (and this is beginning to happen), solar energy will become even more economically viable than it is today. ■

Endnotes

1. "State of the Art: Water Heating" Competitek report. Snowmass, Colo.: Rocky Mountain Institute, Fall 1991.
2. The report compared all options to the "base case" of electric resistance heating, using a cost-effective measurement called the "cost of saved energy" or CSE. The cost and potential saving estimates given in this report were stated in the context of savings for the whole United States, but are equally valid for individuals who wish to reduce water heating in their homes.

   Numbers in the report represent the technical potential for savings. Although very large savings can be achieved relatively easily and at a low cost, it is not likely that the full potential can be reached without a serious commitment to removing the barriers that impede the progress of achieving this potential.
3. The average residential electric water heater uses about 4,480 kWh/yr, costing about $358/yr.