Solar Water Heating for the U.S. Postal Service

Well-Proven Technology Pays off in the Right Application

Energy managers within the U.S. Postal Service (USPS) are working hard to increase energy efficiency and substitute renewable energy wherever economically feasible. *Solar water heating* is a well-proven and readily available technology that can significantly reduce energy costs at many USPS facilities. Additionally, other proven water heating savings measures beyond solar include *Reduced-kW heating elements*, *Replacement with smaller heaters*, *Tankless demand heaters*, and *Heater insulation blankets.*

Key criteria for selecting solar and/or other water heater energy efficiency measures include: (1) the source/cold water temperature, (2) the end use (lavatory, custodial, or food service), (3) the capacity of the existing water heater, (4) the utility rates, and (5) the climate zone. Cost effectiveness will vary considerably from facility to facility, and solar is best suited to replace electric or otherwise expensive water heating. The guidelines presented herein are based on a 6-month detailed study of hot water use and costs at two USPS P&DCs, one MPO, and two Branch offices.

There are dozens of certified solar collectors and systems available, and an adequate number of skilled system installers in most regions. Solar water heating is a mature and reliable technology with over 1 million installations; past problems are unlikely with today's systems. Federal agencies that have installed solar water heaters include EPA, GSA, DOE, and DOD. FEMP Technology Alert DOE/GO-10098-570 provides an in-depth technical discussion of Solar Water Heating with case studies.

Water Heating Efficiency Measures

In general, savings are generated by reducing the loss of heat through the tank sides and by reducing the power demand of the heater element. Cost-effectiveness depends on the size and Wattage of the heater. Solar water heating panels are among the most cost effective water heating technologies. Other measures that can provide additional savings or a faster payback are described below as well.

First, a word about *timers*. Many USPS water heaters are fitted with time-of-day controls, which are supposed to turn off the heaters during unoccupied periods. In concept, energy is saved because tank-losses fall as the water cools. If the timer could be set to turn the heater off just after the last usage, with the water in the tank still cold, annual savings would be $20 to $80 per year. In most real applications, the tank is filled with hot water and losses continue even with the heater turned off. Actual savings range from nil to $20 per year.

Reduced-kW Element

Hot water usage at USPS Branches, Stations, Annexes, and MPOs is typically 5 to 20 gallons per day, mostly from lavatory hand washing and perhaps filling a mop bucket. The Wattage of a standard 30-gallon water heater is excessive for these end uses. Heaters of this size typically have 2500- to 4500-Watt heating elements and can heat 15 to 45 gallons per hour of water to 115 degrees F. Replacement with a 1000-Watt element will meet the actual usage needs, while significantly reducing electric demand charges.

The Satellite Beach USPS Branch serves as an excellent example of potential savings. The annual demand charge for a 3100-Watt heating element under FPL rate schedule GSD-1 ($8.40 per kW) is $313 per year and

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accounts for 67% of water heater costs at the facility. Replacement with 1000-Watt elements will save $212 per year. Capacity will be reduced to 8.4 gallons of hot water per hour, which is more than adequate for the actual usage of 8 gallons per day at this facility.

Replace with a Smaller Heater

Downsizing of the entire water heater will provide tank-loss savings in addition to the reduced-kW element savings described above. A 40-gallon tank is excessive for the 5 to 20 gallon-per-day hot water usage at most USPS Branches, Stations, Annexes, and MPOs. A smaller heater has less surface area and wastes less heat to the ambient air. For example, heat loss from a 40-gallon heater is about 210 Watts and accounts for $93 per year at the Satellite Beach Branch. For comparison, heat loss from the smaller 10-gallon heater at Suntree Branch is just 110 Watts giving a savings from the smaller heater of $46 per year.

Tankless Demand Heater

Replacement of the entire heater with a tankless demand heater will eliminate tank losses altogether. The drawback is that the kW-demand of tankless heaters is higher since the units must be able to heat water instantaneously as fast as it is being used. A 3000-Watt tankless unit can provide only 0.6 gallons per minute of 110 degree F water, just enough for one or two lavatory faucets. Filling a 5-gallon mop bucket would take several minutes with such a heater. A 6000-Watt tankless unit can provide twice the hot water flow, but the extra demand charges would double water heating costs. Moreover, tankless heaters are not compatible with solar panels. Nonetheless, replacement of the 30-gallon heater at the Satellite Beach Branch with a 3000-Watt tankless unit (or two 1500-Watt units) would provide savings of $133 per year.

Heater Insulation Blanket

Water heater tanks come insulated with polyurethane-foam or fiberglass between the tank and the outer case, typically with an R-value of R-6 to R-9. One exception is high-performance commercial heaters with 3-inches of R-16 insulation. Some manufacturers claim that additional insulation is not needed. However, additional insulation will always reduce standby losses and space cooling load, and cut energy costs. For example, adding a blanket to the USPS Satellite Beach Branch 30-gallon heater will save $62 per year. Adding a blanket to Suntree's newly installed 10-gallon heater will save $21 per year.

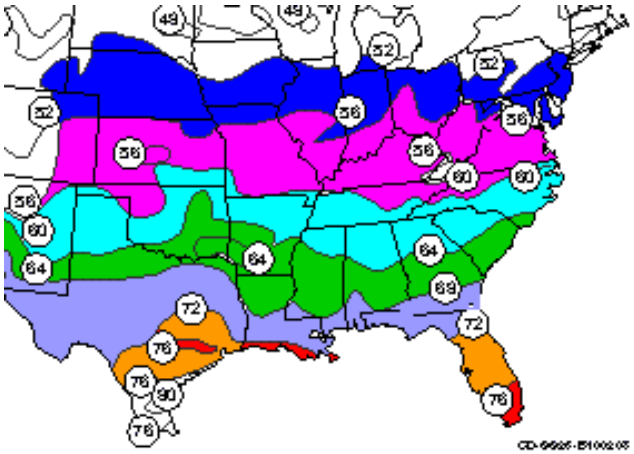
Blankets come in a standard size (48"x75") that will cover any common water heater up to 65-gallons. The blankets come in two thicknesses and cost less than $20. The 2" thickness adds an extra R-6.7 rating's worth of insulation to a heater, and the 3" thickness adds an extra R-10. Choose an R-10 blanket for any electric water heater, or for any heater that sits in unheated space. Use an R-6.7 blanket for a gas water heater that sits in heated space.

Add a Solar Heating Panel

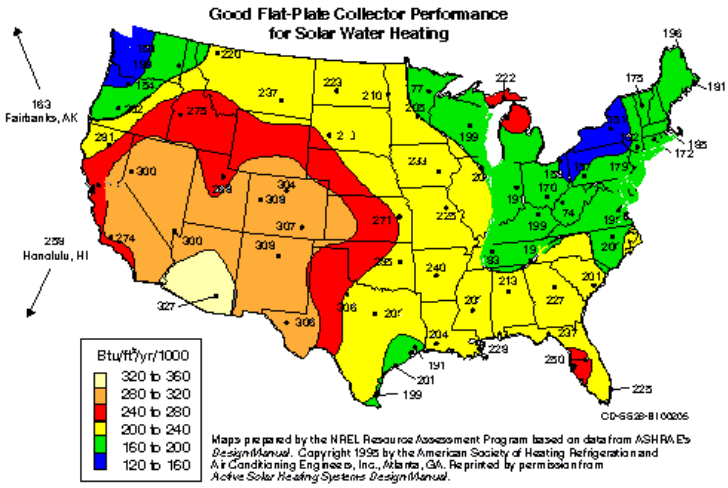
Hot water usage at a typical P&DC's break room/restroom area is about 100 gallons per day, mostly from lavatory hand washing and kitchen usage. Such high water use, combined with high demand charges and/or an inefficient heater can make a solar system economically feasible.

Because of the low usage of 5 to 20 gallons of hot water per day at USPS Branches, Stations, Annexes, and MPOs, it is feasible to add a solar panel to an existing hot water tank, without replacing the water heater. This approach uses the existing hot water heater as the solar storage tank, and is more cost effective than purchase of a compete system. Savings can be 70% or more because the solar panel provides most of the heat needed to provide hot water as well as overcome tank losses. In addition, there are kW-demand savings because the

Map of average water temperature for Southeast US.



Annual solar radiation availability map.

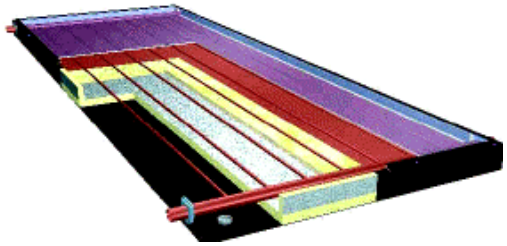


heating element will not come on for 6 to 9 months of the year.

For example, a 4'x10' solar collector (40 square feet of selective absorber area) will provide about 9,200 kBtu of heat per year, enough to satisfy 86% of the heating needed at USPS Satellite Beach Branch. Annual savings will be $390, this is an 90% savings. Installed cost for this facility will be $1700, giving a 4½ -year payback period.

Of course, savings and cost effectiveness varies by region according to the source-water temperature and the available solar radiation. If the Satellite Beach Branch were moved from Central Florida to West Tennessee, where the source water averages 62 degrees F instead of 75 degrees F and solar radiation is 19% less, savings would be about $350 per year and the payback period would be 4.8 years. For comparison, a worst-case location would be Northern Pennsylvania where the source water averages 50 degrees F and solar radiation is 35% less: savings would be about $300 per year and the payback period would be 5½ years. Nonetheless, solar panel economics have more to do with the particular heater, utility rates, and water usage than with the location of the facility, as long as there are no solar obstructions nearby such as tall trees or buildings.

Cutaway view of a solar water-heating panel.



Size	Area sq ft	Btu/Day	Btu/ft²	COST
3½ x 6	**21**	19,000	900	$ 703
3 x 8	**25**	22,200	903	$ 723
4 x 8	**33**	30,300	924	$ 852
4 x 10	**41**	37,800	925	$ 993

Another example where solar makes economic sense is the Mid-Florida P&DC's 65-gallon heater. Here, two 4'x10' solar collectors (80 square feet of selective absorber area) will provide about 50,300 kBtu of heat per day, enough to satisfy 80% of the heating needed for the breakroom / main restroom area of the facility. Annual savings will be $973; this is a 91% savings. Installed cost for this facility will be $3,230 giving a payback period of less than 3½ years.

Economics and Payback Periods

Electronic *timers* with a memory cost $110, and have a total installed cost of about $175. Best-case payback period would be 9 years. The cost of enabling an existing timer is minor, and is worthwhile in most cases. However, the clock setting needs to be checked/set periodically.

The cost of a *reduced-kW heating element* is less than $10 and installation takes about one hour, for a total installed cost of about $70. Depending on the Wattage of the original element and the utility kW-demand rate, annual savings from installation of lower Wattage elements will range from $60 to over $400 when properly sized. Payback period is typically less than one year.

Compact electric water heaters are available in a range of sizes from 6-gallons to 19-gallons. Heater prices range from $125 to $190 and a typical installation labor cost is $120. Depending on the size and condition of the existing heater, annual savings will range from $80 to over $250. Typical payback periods range from 1 to 3½ years.

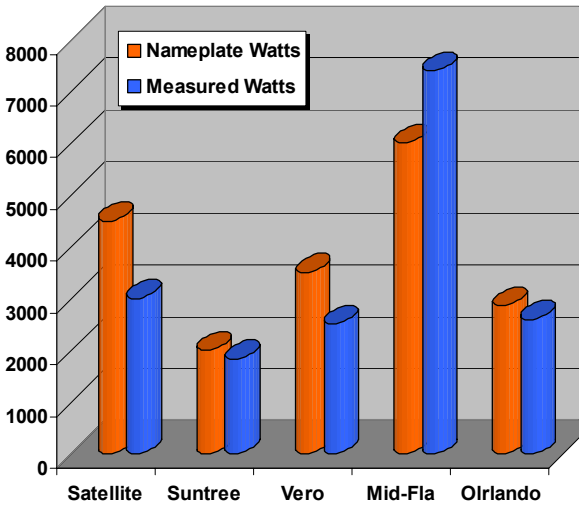
Tankless instantaneous demand heaters are available in a range of sizes from 1.5-kW to 9-kW. Heater prices range from $170 to $250, and a typical installation labor cost is $125. Depending on the size and Wattage of the existing heater, annual savings will range from $50 to $150. Typical payback periods range from 2½ to 5 years.

A *heater insulation blanket* costs about $20 and takes about one hour to install, for a total installed cost of about $80. Depending on the size and condition of the existing heater, annual savings will range from $25 to $65. Typical payback periods range from 1½ to 3 years.

Costs for high quality, certified *solar heating panels* are shown in the table at left. Desirable features include copper tubes and sheet with a selective black nickel chrome coating, stainless steel hardware, and R-12 back and side insulation In addition to the panel, a small circulating pump, a controller with a freeze protection cycle, solenoid stop valves, and a freeze protection valve that drains the collector when the temperature dips below 35 degrees F is needed. Total installed cost ranges from $1,400 to $3,500. Annual savings from a properly applied system will be 70% to 90% of standard water heater costs – about $200 to $1,500 per year depending on hot water usage. Typical payback periods for a value engineered installation range from 3 to 7½ years.

Areawide Impact

Estimated water heating costs for the approximately 1000 Southeast Area USPS buildings in the size range of 3,600 to 36,000 square feet is about $320,000 per year. These facilities account for 40% of Area energy costs**. The combined power draw of these water heaters is about 3 Megawatts – enough to fully power two large USPS Processing & Distribution centers.** A properly applied combination of reduced-kW heating elements, insulation, heater replacements, enabling existing



timers, and solar panels would produce approximately $250,000 per year in energy savings[1]. The estimated implementation cost to achieve these savings in the Southeast Area is $850,000, giving a payback period of less than 3½ years.

Case Studies of Hot Water Costs

To evaluate the possible application of solar hot water heating at USPS sites, data logging systems were installed at five USPS test sites (Mid-Fla P&DC, Orlando P&DC, Suntree Branch, Satellite Beach Branch, and Vero MPO). The data loggers continuously measure and record hot water consumption, water inlet temperature, heater outlet temperature, and electric power use. Detailed findings are discussed on the following pages.

Demand charges account for 50% to 70% of the electric operating cost of these water heaters. In most cases, the heaters are much oversized. Remarkably, heater element power demands were significantly different from the nameplate ratings. For example, the unit at Satellite draws 3,067 Watts, even though the nameplate shows (2) 4,500 Watt elements. Measured differences ranged from 33% less to 23% higher. This means that while nameplate numbers are not reliable for use in accurately analyzing water heater energy costs, they can be used for rough estimates.

Tank losses are even more significant than what is usually estimated from handbook data. Tank losses account for more electric use than the actual heating of water at Satellite, Suntree, and Vero Beach. Water heating itself accounts for only 4 to 14% of total heater electric costs. Long-term monitoring demonstrated that hot water use per day is much less than anticipated: about 4 to 17 gallons per day at Satellite, Suntree and Vero, (40 employees) and about 90 to 110 gallons per day at Mid-Florida (300 employees) and Orlando P&DC.

Suggested Action Plan

Of the five energy saving measures described above, solar panels provide the most dollar savings and should be installed wherever economically feasible. The reduced-kW heating element gives the fastest payback, although annual savings are considerably less. The minimum recommended Energy Conservation Measure (ECM) is to install both a reduced-kW element and an insulation blanket. If the heater is in poor condition, replacement with a smaller heater is recommended, which can be fitted with a reduced-kW element and an insulation blanket as well.

A valuable economy of scale could arise from District-wide water heater efficiency programs, instead of implementing on a site-by-site basis. A District plan could be carried out using the *"Two Men & a Truck"* mechanism from the USPS Strategic Energy Management Plan (SEMP). ECM selection guidelines are as follows:

1. Based on the number of employees at the site, the hot water end-uses, the utility rates, and the data presented above, roughly estimate the annual water heater electric costs.
2. Reduced-kW elements and insulation blankets should be considered for all sites, unless there is some site-specific condition that would make it impractical to use, or if there is no utility demand charge. Enable existing timers if practical to check/reset.
3. If demand charges are more than half of total costs, and/or total costs are estimated to be greater than $450 per year after the element replacement and insulation blanket, install a solar panel onto the existing system.

For More Information

FEMP Help Desk:
(800) DOE-EREC (363-3732)
FEMP Solar Water Heating Web Site:
www.eren.doe.gov/femp/prodtech/sw_solar.html

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www.advantekinc.com/engineering

Solar Collector Certification Ratings
www.fsec.ucf.edu/Solar/TESTCERT/COLLECTR/tprdhw.htm

SunEarth Solar Thermal Products:
www.sunearthinc.com

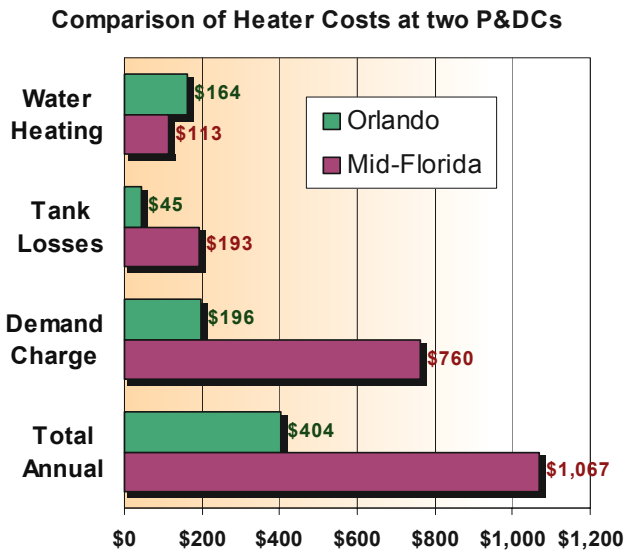
(not to be construed as an endorsement)

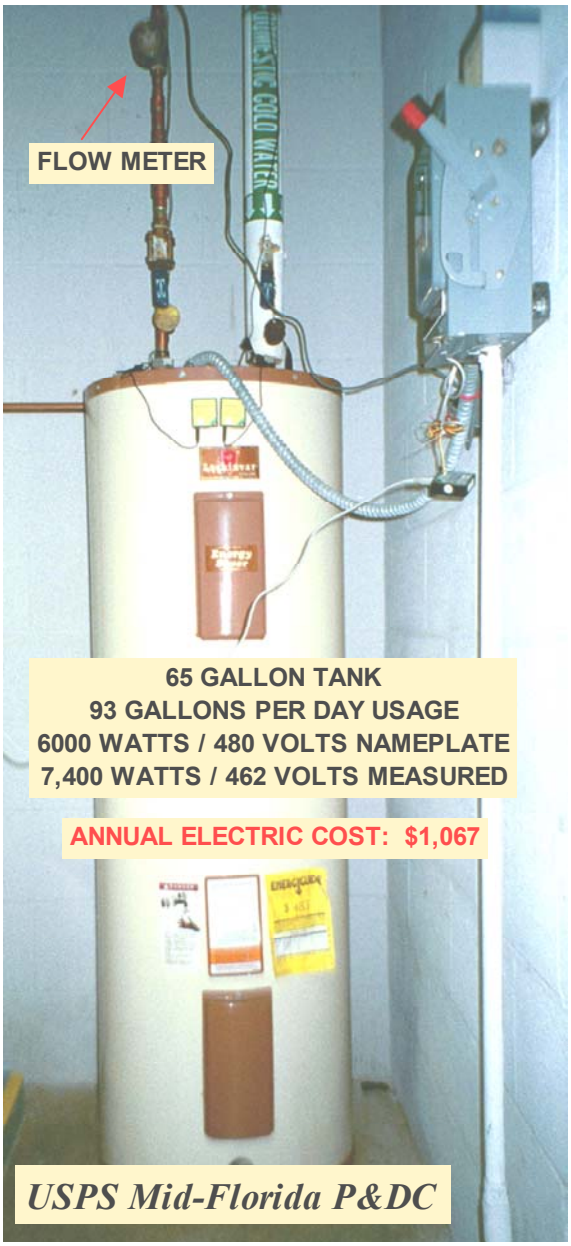
[1] Estimate assumes that 90% of heaters would benefit from a reduced-kW element and tank insulation, 30% of heaters would be replaced, and 30% would be fitted with solar panels. Average rates of $5/kW and $0.05/kWh.

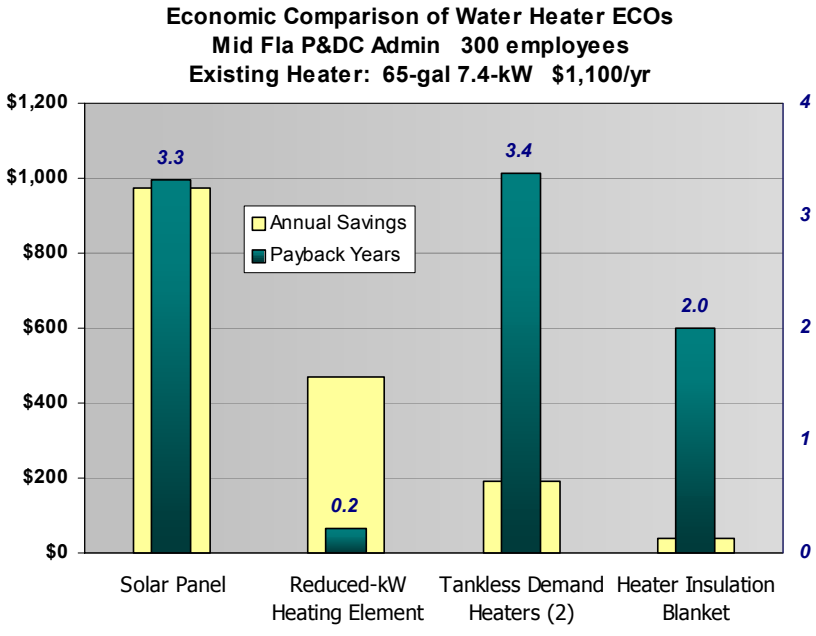
Case Study: Processing & Distribution Centers

The water heating costs at two P&DCs with virtually identical hot water usage of about 100 gallons per day were compared: the Orlando P&DC and the Mid-Florida P&DC. Orlando's heater is a 30-gallon, 2854-Watt *Mor-Flo* unit. Mid-Florida has a 65-gallon, 6000-Watt 3-phase *Lochinvar* heater. The cost differences are striking: About $400 per year at Orlando versus $1,000 at Mid-Florida.

Why the huge difference? As shown in the bar chart below, tank losses and demand charges are about four times higher for Mid-Florida. The reasons are evident when you see the Mid-Florida unit's much bigger and older tank and the much larger heating element, even when adjusting costs to reflect Orlando's 23% lower electric rates. Orlando's newer, right-sized unit produces hot water much more efficiently. In fact, the only worthwhile measure for improving the Orlando heater is an insulation blanket, which would have a payback period of 4 years. The Energy Factor (EF) is a value that compares the real world, as installed efficiency of any water heater. EF is the fraction of the energy consumed by the water heater that is actually delivered as hot water. EF for Orlando is 0.79 versus 0.41 for the Mid-Florida unit. Mid-Florida would benefit by installation of solar panels, a reduced-kW heating element, and an insulation blanket.







Case Study: Main Post Office and Branches

As the pie chart below shows that only 4% of the water heater energy costs at Satellite Branch are from actual hot water use, this is a very inefficient system. Nonetheless, Satellite is equipped with a standard 40-gallon, 4500-Watt electric water heater like those found in most USPS buildings. Total annual water heating costs at the test sites ranged from $200 at the Vero MPO to $275 at Suntree Branch, to $422 at the Satellite Beach Branch, with all facilities reporting 40 to 50 employees and sized from 6,000 to 16,000 square feet. Vero has the lowest cost because the utility demand rate was $3.40 versus $8.12 per kW, and Suntree saved because a new 10-gallon, 2000-Watt water heater was installed at the start of the test.

Most of the savings opportunity at these sites comes from electric demand charges and the large kW draw of the heating element relative to the small quantity of hot water used. A reduced kW element will lower demand charges, and a smaller heater will result in less tank losses. A solar panel will eliminate demand charges for much of the year as well as offsetting tank losses with free solar heat.

The Energy Factor (EF) is a value that compares the real world, as installed efficiency of any water heater. EF is the fraction of the energy consumed by the water heater that is actually delivered as hot water. EF ranged from 0.13 at Satellite and 0.18 at Vero, to 0.43 at Suntree; with Suntree's new heater, less than half the fraction of the electricity consumed by the heater was wasted as tank losses. An EF goal for these types of facilities would be 0.50 to 0.70.