Harpiris Energy

25205 Baronet Road, Corral de Tierra, California 93908

July 30, 2009

Public Utilities Commission
465 South King Street, #103
Honolulu, Hawaii 96813

Regarding: Docket 2008-0249

Dear Chairman Caliboso:

Harpiris Energy respectfully submits these comments in response to your July 1 decision establishing standards for Solar Water Heating (SWH) systems. We applaud the efforts of Hawaii to increase the penetration of SWH by mandating it on all new residential construction. However, we believe the decision to adopt the Residential Solar Water Heating Systems (RSWHS) Standards (aka HECO program) instead of the Solar Ratings and Certification Corporation's (SRCC) OG-300 standard will have a detrimental effect on the long-term sustainability of the solar water heating industry in Hawaii. The use solely of the RSWHS Standards to qualify for this mandate will limit consumer choice, stifle technological innovation, and increase the cost of SWH systems for Hawaii consumers.

- **The RSWHS Standards limits consumer choice:** The RSWHS Standards will significantly limit the number of SWH technologies that qualify for the mandate. Of the six most common technologies, only two meet the 90 percent minimum solar fraction of the RSWHS (Table 1).
- **The RSWHS Standards stifles innovation:** The 90 percent solar fraction requirement that is at the center of the RSWHS Standards effectively limits many innovative, low cost SWH technologies that are both more cost-effective and reliable from participating in the new residential construction market for SWH in Hawaii.
- **The RSWHS Standards puts Hawaii out of sync with the rest of the U.S. and the world:** The SRCC OG-300 certification is used by all domestic SWH incentive programs and the Federal Investment Tax Credit. SRCC is addressing all of the technical issues raised by HSEA. Furthermore, all manufacturers active in the Hawaii market already have OG-300 certified systems for their other markets. Passive thermosiphon and ICS SWH systems (which do not meet the 90 percent minimum solar fraction of the RSWHS Standards) dominate tropical SWH markets around the world, from Australia to Southern Europe and Asia.
- **Participation of SRCC OG-300 certified SWH systems will reduce SWH costs:** If Hawaii were to allow all OG-300 certified SWH systems to be eligible to meet the mandate for new residential construction, the average price of a SWH system will decrease due to greater choice and competition for both new and retrofit installations, which in turn will further support the installation of ever greater numbers of SWH systems in Hawaii. The RSWHS Standards will add $4,000 to $10,000 to the cost of every new housing unit in Hawaii. The 90 percent threshold in the RSWHS Standards often requires adding an additional collector than would normally be needed, adding $1,500 to the system cost to save about $30 per year in energy costs.

For these reasons, we strongly recommend that the Public Utilities Commission consider modifying the eligibility requirements it adopted on July 1st to allow the SRCC OG-300 certification to be used along with the RSWHS Standards to qualify for the new construction mandate.

Consumer Choice

The major SWH system sold and certified in the U.S. are shown in Table 1.

Table 1: Major U.S. SWH System Classifications

System Classification			Installed price	Typical HI Solar Fraction
Active	Direct	Open-loop	$7,300[1]	90%
	Indirect	Glycol closed-loop	$7,500	90%
		Drainback copper	$8,000	85%
		Drainback polymer[2]	$4,500	65%
Passive	Thermosiphon[3]		$7,000	75%
	Integrated Collector Storage	Direct copper	$6,500	65%
		Indirect polymer[4]	$3,500	60%

Only direct open-loop active SWH systems are sold with regularity in Hawaii. Glycol and drainback active systems are more complicated in order to survive freezing, which is not an issue in Hawaii. The other four system types have, in effect, been shut out of the Hawaii market because of the 90 percent minimum solar fraction in the HECO rebate. Our passive polymer ICS system is more cost-effective than direct open-loop systems even without the $1,000 HECO rebate, but many customers mistakenly believe that only HECO-approved products are viable and cost-effective SWH solutions. The decision to adopt the HECO program for the new construction mandate will create a legal barrier to go along with the perceived one, further discouraging alternative SWH manufacturers from marketing their products in Hawaii. This denies both new construction and retrofit customers the most innovative, inexpensive, and reliable technologies in the SWH market.

The drainback active and polymer ICS systems were developed in the last decade by firms in California with significant technical and financial support from the U.S. Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL). The RSWHS Standards shut out Hawaii customer from these two innovative and cost-effective solutions that are quickly gaining popularity in the U.S. Sunbelt. In addition, the RSWHS Standards disqualify the traditional thermosiphon and ICS systems that are the predominant system types in tropical climates.

Customer choice is particularly important with regard to the new construction mandate in Act 204. Under these circumstances, the homebuilder will make the SWH purchase on behalf of the homebuyer. Given the stakes involved, both parties naturally emphasize price and reliability. In retrofit SWH sales in Hawaii, the price signal is weakened by incentives that cover 55 to 70 percent of the total cost. As a result, many retrofit customers will likely continue to prefer the maximum performance of the direct open-loop system, even though they require annual or bi-annual inspection by a specialized SWH contractor. However, the new home builder and purchaser will not benefit from the 35 percent state tax credit or the $1,000 HECO rebate. More importantly, the poor track record of active SWH systems with regard to reliability will frighten away both types of customers. (See page 5 for details.) For the retrofit customer motivated by their carbon footprint and/or utility bill costs, the additional maintenance may be justifiable. But new home buyers will include a sizable percentage who do not share such motivations,

[1] Average of three quotes for a two-person household in Honolulu in 2008

[2] The Revolution drainback polymer system is manufactured by Fafco

[3] Although thermosiphon systems currently qualify for the HECO program, their actual performance is well below the 90% minimum solar fraction because the RSWHS does not account for the high tank losses.

[4] The SunCache polymer ICS is manufactured by Harpiris Energy

and are therefore less likely to perform required maintenance. If anything, the commission should encourage the inherent reliability of passive SWH systems for new home construction to maximize savings persistence.

SWH is Overpriced in Hawaii

In 2008, we solicited three SWH bids for a two-person household in Honolulu, with the results shown in Table 2. All three contractors claimed their quoted system would qualify for the HECO rebate. The 35 percent state tax credit is maxed-out for a two collector system, and the HECO rebate is $1,000 regardless of the number of collectors needed to reach the 90 percent solar fraction threshold. This makes the economics much less attractive for larger households that are forced by RSWHS to buy three or more collectors.

Table 2: SWH System Bids for 2-person Household in Honolulu (2008)

Installer	Quoted System Specs	Price	Sales Tax	Total Cost	After Incentives
A	Two 3x7 collectors + 80 gal tank	$5,800	$273	$6,073	$1,776
B	Two 4x8 collectors + 120 gal tank	$7,890	$372	$8,262	$3,508
C	Two 4x8 collectors + 120 gal tank	$8,290	$390	$8,680	$3,801

Despite a per-capita SWH penetration that is 30 times that of the next largest U.S. market (Florida), direct open-loop active systems in Hawaii are on-par pricewise with more complicated active systems used in other markets. When the $1,000 of additional equipment (heat exchanger, expansion tank, glycol) required for indirect closed-loop active systems is included, direct open-loop SWH systems in Hawaii are actually more expensive than in other U.S. SWH markets. In South Florida where the risk of freeze is remote enough to allow direct open-loop active systems, installed costs are $1,000 less than in Hawaii.

Active systems also have higher service costs. Hawaii installers sell annual and bi-annual service plans for 10 years that cost from $400 to $1,400 if purchased with a new system. Passive systems require little maintenance.

Limited Competition

Limited competition among hardware suppliers and installers has resulted in unreasonably high prices in the Hawaii market. Generous incentives have increased market uptake, but they have also blurred the price signal to the consumers, making them unaware of dramatic increases in recent years. Prices of conventional flat-plate collectors or solar storage tanks are unlikely to decrease with the new construction mandate. *Economies of scale are absent in the Hawaii SWH market, and there is no reason to assume this will change with the new construction mandate.*

Figure 1 shows that the Hawaii market has stagnated despite high energy prices and generous incentives, while SWH has taken off in other states. Once 50% of the national market, Hawaii's share has fallen below 20%. High prices caused by lack of competition are the primary cause. The 2008-0249 PUC decision will reward this behavior by granting the Hawaii SWH industry substantial growth while maintaining their non-competitive hold on the market. Expanding the decision to include all OG-300 certified systems

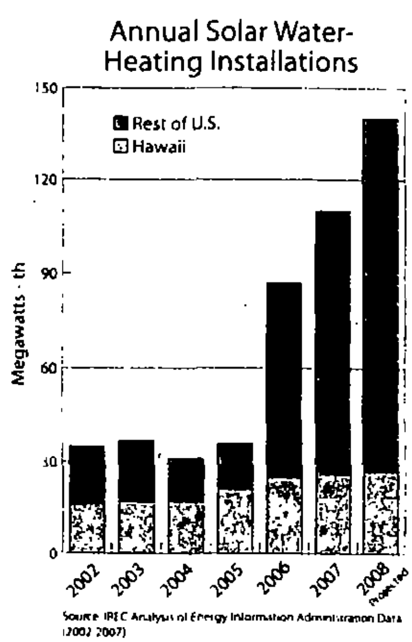


Figure 1: U.S. SWH Market

would not only benefit new housing customers, but also retrofit SWH customers by introducing alternative technologies to the marketplace.

Acceptance of lower-cost SWH technologies would increase competitive pressure on hardware manufacturers and distributors. Because the alternative systems are easier to install than direct open-loop systems, the barrier to entry for installers would be reduced and competition would increase amongst installers, benefitting both the retrofit and new construction markets. The innovative polymer drainback and polymer ICS systems pioneered streamlined installation and all-in-one packaging in the SWH market, making it easy for professional plumbers and general contractors to reliably install SWH without any formal training. (Both are even marketing for do-it-yourself homeowners.) Not only will this increase the pool of installers, but it will allow homebuilders to use their existing plumbing contractors for the SWH installation. Direct open-loop systems will require bringing in a SWH specialist contractor at additional expense, an obvious goal of the existing SWH installation firms.

Higher Housing Costs

Both the 35 percent state tax credit and $1,000 HECO rebate are likely to be withheld from new home builders and buyers, leaving only the 30 percent federal tax credit to be claimed. As a result, SWH systems in new construction will cost at least $4,000 (after incentives) per housing unit, and in the case of larger homes more than $10,000. Early bids for new construction projects confirm this. In the current economy, builders will not start new projects unless they are confident they can pass the full cost on to the buyer.

Passive SWH systems do not consume indoor floorspace. When compared to the option of passive system with an exterior-mounted tankless backup water heater, direct open-loop active SWH systems consume an additional 10 square feet or more. At a cost of $200 per square foot, and even after taking into account the incremental cost of the tankless water heater, an open-loop active SWH system will add at least $1,000 to the construction costs of a new home (plus the system itself). Homes with smaller footprints will have less interior living space than with either small storage or tankless water heaters.

The Act 204 SWH mandate will not only affect builders of luxury golf villas, but also rural communities that are trying to provide badly-needed housing. Military housing will cost more to build, and innovative green building projects will have to reduce their budget elsewhere. The result will be an across-the-board reduction in quality and increase in housing costs.

Barring Innovation

In the late 1990s, the National Renewable Energy Laboratory determined that polymer materials had the greatest potential to lower material and installation costs of SWH systems. DOE and NREL funded two private teams to develop polymer SWH systems, and both resulted in market introductions in the last two years. Fafco's Revolution indirect drainback active system combines proven pool collector technology with all-in-one packaging and is the lowest-priced active system on the market. Harpiris Energy's SunCache ICS uses polymer materials to reduce the amount of copper used to make an ICS collector from 280 to 15 pounds. Installation requires an average of 8 man-hours, and a Hawaii crew holds the current record for a first-time installation, needing just 6 man-hours. Installed in 2002, the first SunCache unit has been joined in the field by more than 100 prototype and production units with call-back rates of less than 5 percent. A SWH report recently released by a national lab referred to the SunCache polymer ICS system as "the only truly new product" developed in the U.S. since the 1980s.[5] Revolution and SunCache

---

[5] *Assembly and Comparison of Available Solar Hot Water System Reliability Databases and Information*, David Menicucci, Sandia National Laboratories, 2009, p. 11.

are the only two SWH systems that have been certified by SRCC for installation with PEX pipe, simplifying installation and reducing cost.

Barring the Most Cost-Effective and Inexpensive Systems

Table 1 shows that the Hawaii market has been denied the lowest-priced and most cost-effective SWH systems that are available in other U.S. markets. In Table 2, the most expensive quote results in a payback of 5 years even with three levels of incentives. Minus the 35 percent state tax credit and $1,000 HECO rebate, the RSWHS Standards will result in simple paybacks of more than 10 years.

Barring the Most Reliable System Types

Sandia National Laboratories recently completed a comprehensive study of maintenance records from the majority of U.S. SWH incentive programs over the last two decades. An excerpt from the abstract:

> "This report describes a comprehensive analysis of all of the known major previous research and data regarding the reliability of SHW systems and components. Some important conclusions emerged. First, based on a detailed inspection of ten-year-old systems in Florida, *about half of active systems can be expected to fail within a ten-year period.* Second, valves were identified as the probable cause of a majority of active SHW failures. Third, *passive integral and thermosiphon SHW systems have much lower failure rates than active ones,* probably due to their simple design that employs few mechanical parts. Fourth, it is probable that the existing data about reliability do not reveal the full extent of fielded system failures because most of the data were based on trouble calls. *Often an SHW system owner is not aware of a failure because the backup system silently continues to produce hot water.* Thus, a repair event may not be generated in a timely manner, if at all."[6]

This means that failures reduce the collective savings of active systems by about 25% over the first ten years, placing their actual savings much closer to passive systems. The researchers also noted that "direct systems, which continually pump fresh domestic water through the collectors, would subject the collector to greater potential corrosion."[7] Diagnosing active system failures is also more complicated than for passive systems. The researchers found that active systems have eight different failure modes accounting for at least 5% of failures. ICS systems have just two.

In contrast to HECO's claim of high system reliability, anecdotal evidence suggests that direct active systems in Hawaii are no more reliable than in other parts of the country. Maintenance supervisors working for military housing contractors in Honolulu complain that most systems are not operational, and that there isn't budget to repair them. Had passive systems been selected, a far greater percentage would be operational today and continuing to save energy and reduce operating costs. A similar story has emerged on Molokai, where there is only one person able to service the direct active systems that regularly fail across the island. With no one else to service the systems, this honorable citizen continues to serve his neighbors despite his desire to retire.

By mandating SWH for all new construction in Hawaii, many installations will take place in rural and economically-depressed areas. Because only direct active systems meet the RSWHS Standards, these rural installations will:

- cost more than $10,000 each,
- require outside contractors rather than rely on labor from inside the community, and

[6] Menicucci, Sandia National Laboratories, 2009, p. 3.

[7] Menicucci, Sandia National Laboratories, 2009, p. 32.

- be short-lived.

The Hawaii SWH Market is Out-of-Sync with U.S. and Tropical Markets

Common sense dictates that SWH systems in Hawaii should be smaller than in the Continental U.S. due to the better solar resource and lower water heating loads. Unfortunately, the RSWHS Standards require Hawaii consumers to buy larger systems than in the Continental U.S. Systems with more than two collectors are rare in the Continental U.S., but the RSWHS Standards often requires it for households with four or more occupants. In the Continental U.S., a 75 percent solar fraction is considered high-performance.

The SRCC OG-300 certification is used by all domestic SWH incentive programs except for the RSWHS Standards. (Florida uses a closely related standard from the Florida Solar Energy Center, an SRCC sister organization.) SRCC has recently established a provisional OG-300 certification in response to complaints about long certification lead times, and all manufacturers active in the Hawaii market already have OG-300 certified systems for their other markets. All of the system types shown in Table 1 are popular in the U.S. Sunbelt locations.

Passive SWH systems dominate tropical SWH markets around the world. Thermosiphons are the mainstay of the Australian market and are also popular in Southern Europe. ICS systems, both manufactured and home-built, are the most common system type in Latin America and Asia.

The 90 Percent Minimum Solar Fraction is Excessively High

Harpiris Energy recently hired Thermal Energy System Specialists (TESS) to evaluate the annual performance of direct open-loop active systems in Honolulu. TESS is the leading U.S. consulting firm in the area of annual thermal modeling of building systems. TESS maintains the TRNSYS source code, which is used by SWH system designers across the country, and also by SRCC.

Using the same parameters as SRCC uses to generate OG-300 ratings, TESS projected the solar fractions shown in Table 3 for one and two collector systems using painted collectors and 80 gallon tanks.

Table 3: Honolulu Solar Fractions for Direct Open-Loop Active SWH Systems (Source: TESS)

Daily Hot Water Usage (gal/day)	Equivalent # of Occupants	# of 4x8 Collectors	Solar Energy Delivered (kWh)	Annual Solar
32	2	1	883	82%
		2	924	86%
48	2-3	1	1390	86%
		2	1448	90%
64	3-4	1	1864	87%
		2	1971	92%
96	5	1	2608	81%
		2	2891	92%

Recent research indicates that median hot water usage is lower than the 64 gal/day value used for many years by water heating researchers and engineers. Many houses monitored under the Building America (DOE) program have hot water usage of less than 30 gal/day, but the HECO calculations assume 20 gal/day/person, resulting in oversized systems for smaller households. Table 3 demonstrates that *actual performance of small households will never reach the 90 percent threshold because of parasitic pump energy*. By requiring oversized systems, the 90% threshold is probably self-defeating for smaller households.

For the 48 gal/day and 64 gal/day households that make up the largest part of the population, *the RSWHS Standards forces them to purchase a second collector to achieve the 90 percent threshold, but provides only an additional 4-5 percent of annual savings.* Including installation, a second collector increase system cost by about $1,500. Because of the $1,000 HECO rebate, homeowners have been willing to accept the larger system. However, *the second collector only saves them an additional $30 per year, resulting in a 17 year payback for the second collector even after the $1,000 HECO rebate.* Even if we allow for a lower incremental cost of $1,000 in new construction, *the new home buyer will have a 33 year payback for the second* collector because they will not qualify for the HECO rebate. This is the reason why active systems on smaller homes in the Continental U.S. typically have only one collector.

TESS' conclusion was that "when economics are factored in, it becomes quickly evident that obtaining a very high solar fraction is cost prohibitive for larger dwellings." The TESS report is attached to this letter.

It is highly unlikely that the systems that have been installed under the HECO rebate are operating with an *aggregate* solar fraction above 90 percent. For direct open-loop systems, 25 percent of the systems are estimated to be non-operational (based on the Sandia study), and in small households the pump parasitic losses make it impossible. Technically, the HECO program *does* allow thermosiphon systems, but in practice they are rare due to structural concerns and higher tank costs. The HECO program specifies the required storage tank volume, but doesn't take into account storage tank performance. This is fine for indoor storage tanks where the performance is comparable between manufacturers. However, due to their roof-mounted storage tank location, thermosiphon systems have much higher tank losses than active (pumped) systems, which is clear from the SRCC OG-300 system ratings for thermosiphon system shown in Table 4.

Every thermosiphon systems installed under the HECO rebate has a solar fraction below 90 percent. If the PUC's Decision 2008-0249 is not changed, thermosiphon systems should NOT be allowed to qualify for either program.

Table 4: SRCC Projections for Typical Thermosiphon Systems in Honolulu

SRCC OG-300 System #	# of Collectors	Storage Tank Volume (gal)	Hot Water Usage (gal/day)	Solar Fraction
2001009B	2	80	64	71%
2001009D	3	120	64	83%

Table 3 and Table 4 demonstrate the main drawback of the RSWHS Standards. Although it does do a better job than OG-300 of accounting for varying hot water usage and collector orientation, *it considers only the performance of the collector and ignores critical factors that impact system performance such as storage tank behavior and pump parasitic losses.* OG-100 collector ratings are based on an ideal weather scenario, and the HECO program uses rules-of-thumb to adjust for actual tilt and orientation. The OG-300 ratings are based on TRNSYS computer models that use local weather data combined with a realistic draw profile to project the system performance for every hour of the year. **This is the key reason that all other performance-based SWH incentive programs in the U.S. use OG-300.** Many include their own de-rating calculations to account for sub-optimal tilt and orientation similar to the HECO program. Furthermore, SRCC is working hard to bring real-time TRNSYS simulations of OG-300 systems to their website. This will allow anyone to run a TRNSYS simulation of any OG-300 system in any of 83 U.S. locations *while accounting for household size and collector tilt and orientation.* This would appear to be the "Holy Grail" for incentive programs, and would also address all technical concerns raised by HSEA in the 2008-0249 proceeding.

We believe that the objection to the cost of OG-300 certification is unwarranted. SRCC fees are subsidized by DOE and are far less than private certifications. For instance, IAPMO R&T listing for compliance with the Uniform Plumbing Code costs $5,700. Most manufacturers active in Hawaii already have OG-300 certified active open-loop systems with one and two collectors for sales in San Diego and Florida. As shown in Table 3, one collector is sufficient for the majority of Hawaii households.

Background

Manufactured by Harpiris Energy, the SunCache SWH system is the result of a 10-year, $2M R&D effort funded by the Department of Energy and the National Renewable Energy Laboratory. This passive polymer ICS system is the lowest-priced residential-scale renewable energy system certified in the U.S. It has received SRCC OG-300 and Florida Solar Energy Center certification. Formed in June 2008, Harpiris Energy began shipping SunCache units in Q4 2008, after the deadline to become a party to this proceeding. Most early SunCache units are going into a $235,000 demonstration project funded by the California Air Resources Board, and Harpiris Energy just signed a $285,000 grant contract with the California Energy Commission to develop a low-cost solar storage tank for active SWH systems. SunCache has been specified for a major university dormitory project that will house 2,500 students.

SunCache systems are distributed in Hawaii by SunEnergy Hawaii, a Native Hawaiian-owned business. SunEnergy Hawaii will have a SunCache demonstration unit at the BIA home show in Honolulu from July 31 to August 2. If commissioners or staff would like to see this product up-close, please visit us at the RMA booth.

Sincerely,

Eric Lee
President
Harpiris Energy, LLC
eric@harpiris.com
(530) 220-7000

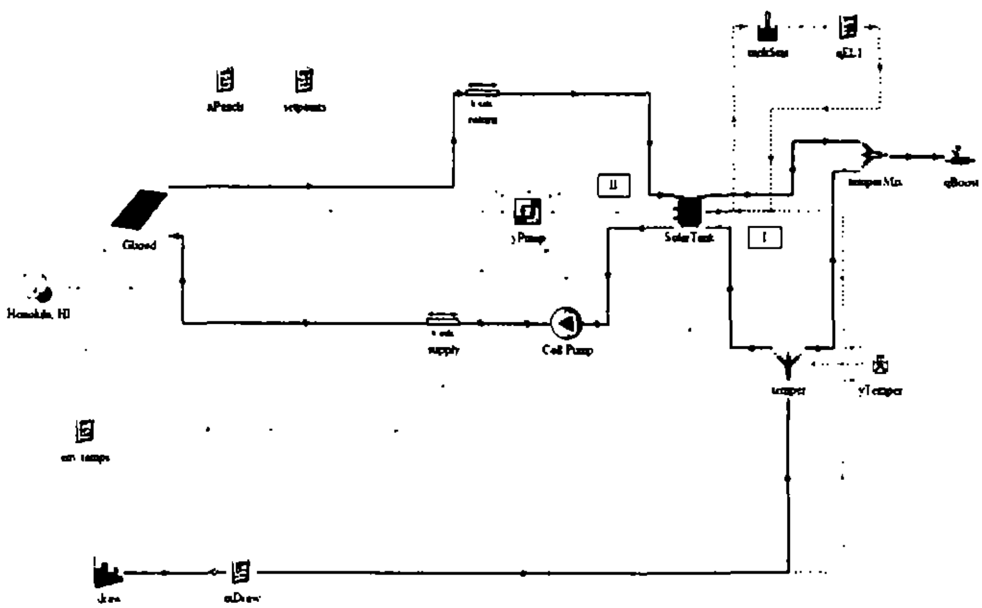
Bernard P. Kea
President
SunEnergy Hawaii, Inc.
bernardkea@hawaiiantel.net
(808) 277-9057

cc: Honorable Mike Gabbard, Chair and Members of the Senate Committee on Energy and Environment

Honorable Hermina M. Morita, Chair and Members of the House Committee on Energy and Environmental Protection

Ray Starling, Public Benefits Fee Administrator, Science Applications International Corporation

Simulations were carried out within the TRNSYS energy modeling environment to investigate the sensitivity of an OG-300 rated single-tank solar domestic water heating system in the Hawaiian climate to number of panels and to total daily water draw. As such systems get larger, they get closer to being able to provide 100% of the needed energy. However, the number of panels and the size of tank needed to get there begins to go up exponentially as the point of diminishing returns is reached. When economics are factored in, it becomes quickly evident that obtaining a very high solar fraction is cost prohibitive for larger dwellings. The following figure shows a schematic diagram of the system modeled.



As many assumptions as possible were taken from the Solar Ratings and Certification Corporation (SRCC)'s "Annual Performance of OG-300 Certified Systems in Honolulu, Hawaii" document. Where assumptions were not clear or were felt to be non-ideal, best-practice simulation assumptions were used based on TESS's previous experience modeling solar domestic water heating systems. A brief synopsis of the simulation assumptions follows:

OG-300 System Basis: Single tank with single electric element auxiliary backup.
Collector: 4x8 (painted) panel with parameters modified from latest published OG-100 numbers to correspond to OG-300 input file. The collector model used in the current simulation accounts for the thermal capacitance of the collector itself where the collector model used in the OG-300 standard input file does not.
Supply and return piping: 7.62m ¾" copper with ¾" foam insulation. The pipe model used in the current simulation accounts for the thermal capacitance of the pipe and insulation (in addition to the thermal capacitance of the fluid) where the pipe model used in the OG-300 standard input accounts only for the fluid capacitance.
Tank: 80 gallon 4.89ft tall R:17 (IP) – R-value modified as per SRCC practice. Single 4500W element at 2/3 height. As per SRCC, liquid is assumed to enter at the point in the tank where the tank temperature and inlet liquid temperature are closest.
Controls: As per the OG-300 input file, the pump turn-on deadband is 2.2 F and the turn-off deadband is 0.
Pump: The pump in the solar loop circulates fluid at the mass flow rate used in the OG-300 input file (222 L/h per collector). There was no indication as to why this particular mass flow rate was chosen in the input file. It is in the neighborhood of the flow rate under published OG-100 collector specifications. The SRCC makes two odd assumptions about the pump power. First, the pump in the system's OG-300 deck draws 84W, which is a very high power for such a small pump. A more typical value would be on the order of 19

W/gpm (18.6W). Second, when they go from a one-panel to a two-panel system, the pump flow rate doubles but it's power stays exactly the same.

Water Draws: The OG-300 daily draw profile for annual simulation was used with total daily draws of 32, 48, 64, 96, and 128 gallons (per day).

Set Points and Mains Temperature: An NREL/Building America mains water temperature profile was used in lieu of the one mentioned in the "Annual Performance of OG-300 Certified Systems in Honolulu, Hawaii" document. It has an average annual mains temperature of 25C as opposed to the 27C used in SRCC simulations. The water tank is maintained at 125F and is tempered to 120F for delivery.

Results

The system was simulated with five different daily water draws, each with a single panel and a two-panel system. The resulting annual solar fractions (as defined by the SRCC) are shown in Table 1. In this set of runs, the power of the pump stays the same whether there are one or two solar panels in the system. As can be seen, the larger the water draw, the bigger the difference made by adding a second panel into the system.

Table 1: Solar Fraction as a Function of Daily Load and Number of Collector Modules

Daily Water Draw [gal/day]	Number of Collector Panels	Solar Contribution [kWh]	Auxiliary Energy [kWh]	Parasitic Energy [kWh]	Solar Fraction [0..1]
32	1	1,076.14	0.51	214.06	0.8206
32	2	1,076.29	0.37	168.97	0.8584
48	1	1,598.13	16.87	232.68	0.8609
48	2	1,614.41	0.57	185.17	0.8965
64	1	2,079.96	73.39	247.66	0.8658
64	2	2,150.01	3.30	199.21	0.9154
96	1	2,805.40	424.68	267.02	0.8073
96	2	3,176.51	53.52	222.78	0.9230
128	1	3,104.78	1,202.01	275.33	0.6913
128	2	4,116.07	190.67	241.19	0.9098

Based on the way that SRCC defines the pump power, there is no parasitic energy penalty to adding a second solar panel onto the system. This assumption does not seem to make sense; if a second collector is added in parallel and the flow rate doubles (which it does in the SRCC input files) then the pressure drop in the system should also approximately double, causing some near doubling in the required pumping power. Furthermore, the high power of the pump causes the systems with a smaller water draw to have an inordinately large penalty due to parasitic energy; consequently, their solar fractions are lower than those of system with larger draws in which the parasitics are smaller relative to the solar energy that can be collected. The simulation were re-run with the 19W/gpm assumption and the following results were obtained.

Table 2: Solar Fraction as a Function of Daily Load and Number of Collector Modules

Daily Water Draw [gal/day]	Number of Collector Panels	Delivered Energy [kWh]	Auxiliary Energy [kWh]	Parasitic Energy [kWh]	Solar Fraction [0..1]
32	1	1,076.14	0.51	46.99	0.9603
32	2	1,076.29	0.37	74.19	0.9377
48	1	1,594.98	20.01	51.08	0.9604
48	2	1,614.41	0.57	81.29	0.9544
64	1	2,072.24	81.12	54.30	0.9434
64	2	2,149.87	3.45	87.45	0.9620
96	1	2,773.37	456.70	58.41	0.8565
96	2	3,174.56	55.46	97.79	0.9573
128	1	3,058.50	1,248.29	60.18	0.7266
128	2	4,110.60	196.14	105.82	0.9369

Again, the larger the water draw, the greater the benefit of adding the second solar panel. Interestingly, with smaller water draws, there is actually a lower solar fraction obtained by adding a second panel. In these cases, the solar fraction is so high that adding a second panel increases parasitic energy use, increases the surface area from which thermal losses occur and increases the average temperature of

the storage tank. The additional losses in this case outweigh the additional gains. At 64 gallons per day draw and above, the trend reverses and the additional gains outweigh the additional losses.
As a point of reference, the energy delivered by and the auxiliary energy required by the system with no solar input is shown in Table 3.

Table 3: Solar Fraction as a Function of Daily Load

Daily Water Draw [gal/day]	Delivered Energy [kWh]	Auxiliary Energy [kWh]	Parasitic Energy [kWh]
32	1,076.69	1,260.61	-
48	1,615.04	1,797.62	-
64	2,153.40	2,335.39	-
96	3,230.15	3,411.62	-
128	4,306.92	4,488.25	-

SANDIA REPORT

SAND2009-2757
Unlimited Release
Printed May 2009

Assembly and Comparison of Available Solar Hot Water System Reliability Databases and Information

David Menicucci

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of Energy's
National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Approved for public release; further dissemination unlimited.

Sandia National Laboratories

SAND2009-2757
Unlimited Release
Printed May 2009

Assembly and Comparison of Available Solar Hot Water System Reliability Databases and Information*

David Menicucci
Building Specialists, Inc.
1521 San Carlos SW
Albuquerque, NM 87104

Sandia Purchase Order No. 836745

Abstract

Solar hot water (SHW) systems have been installed commercially for over 30 years, yet few quantitative details are known about their reliability. This report describes a comprehensive analysis of all of the known major previous research and data regarding the reliability of SHW systems and components. Some important conclusions emerged. First, based on a detailed inspection of ten-year-old systems in Florida, about half of active systems can be expected to fail within a ten-year period. Second, valves were identified as the probable cause of a majority of active SHW failures. Third, passive integral and thermosiphon SHW systems have much lower failure rates than active ones, probably due to their simple design that employs few mechanical parts. Fourth, it is probable that the existing data about reliability do not reveal the full extent of fielded system failures because most of the data were based on trouble calls. Often an SHW system owner is not aware of a failure because the backup system silently continues to produce hot water. Thus, a repair event may not be generated in a timely manner, if at all. This final report for the project provides all of the pertinent details about this study, including the source of the data, the techniques to assure their quality before analysis, the organization of the data into perhaps the most comprehensive reliability database in existence, a detailed statistical analysis, and a list of recommendations for additional critical work. Important recommendations include the inclusion of an alarm on SHW systems to identify a failed system, the need for a scientifically designed study to collect high-quality reliability data that will lead to design improvements and lower costs, and accelerated testing of components that are identified as highly problematic.

* The work described in this report was performed for Sandia National Laboratories under Purchase Order No. 836745.

2. HISTORICAL PERSPECTIVE

Solar hot water (SHW) systems have existed in the United States since the late 1800s. Most of the early systems were simple batch water heaters consisting of a black-painted water storage tank housed inside of an insulated box with a glazing on one side to allow solar radiation to enter. Essentially the tank acted as a repository for hot water that could be used domestically. When applied, it was usually the only source of water heating in the structure (other than the old-fashioned technique of heating a pot of water on the stove).

Through the early part of the 20th century SHW systems slowly began to gain favor as water plumbing became a standard feature in new buildings. However, by the second decade the distribution of natural gas and electricity began to burgeon in major population areas. Mass-produced gas and electric water heaters quickly eclipsed solar systems as the equipment of choice for heating water in commercial, industrial, and domestic settings.

The Arab Oil Embargo in the early 1970s brought public attention to the perils of a national dependence on finite supplies of fossil fuels. The embargo-generated panic produced increasing interest in alternative energy sources, such as solar and wind. The federal and state governments responded with a surge of incentives and funding for renewable technology.

Solar hot water was one of the first solar technologies to emerge as a commercially viable product. By the late 1970s a host of SHW manufacturers were operating in full production, most of them producing systems for domestic and pool water heating. Some of these companies are still operating today.

However, starting in 1980 and for two following decades, the effect of the embargo waned, fossil energy prices settled at affordable levels, and a deregulated market seemed to stabilize fossil-product supplies to easily match steadily growing demand. Government assistance for solar technology dwindled and the SHW industry struggled to compete in the hot water market dominated by relatively low-cost gas- and electrically fired water heaters. Many solar manufacturers failed.

Those SHW companies that remained at the outset of the 21st century produced mostly domestic or pool water heaters using technologies that had not fundamentally changed since their inception. Flat-panel collectors—both glazed and unglazed—and batch heating devices dominated the SHW industry. Over the years SHW systems have seen incremental improvements in manufacturing quality (e.g., welding and brazing), materials (especially ultraviolet [UV] resistant polymers), and component selection such as improved pumps and valves.

The only truly new product was developed early in this century. NREL, working with its contractors, produced a polymer collector, the first of its kind. Although the system is certified by the Solar Rating Certification Corporation (SRCC), few of these systems have been installed commercially.

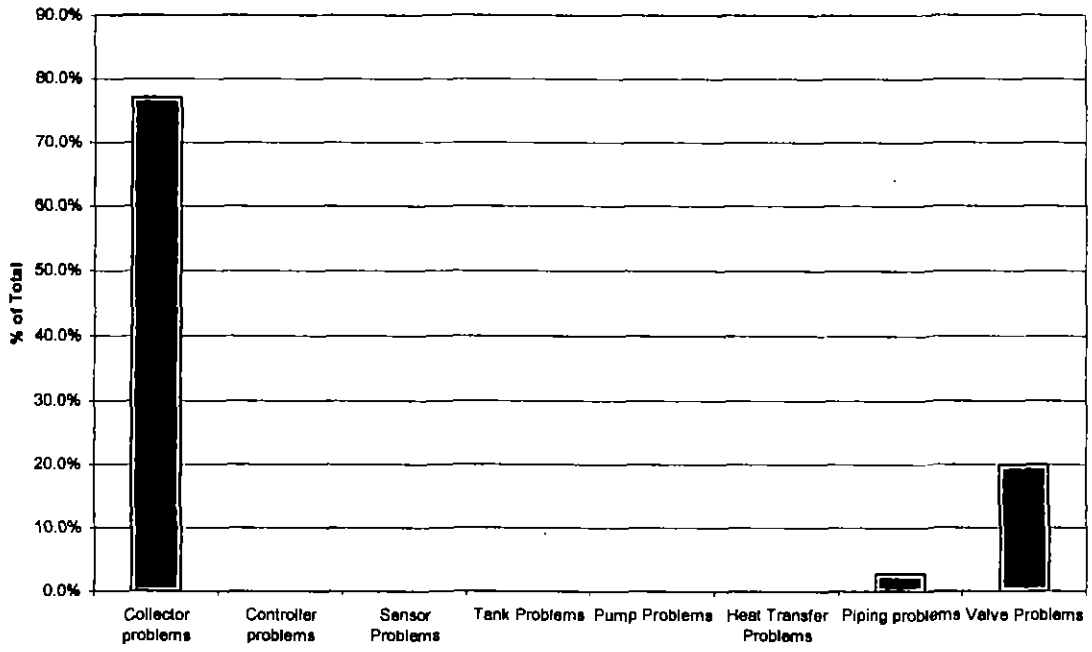


Figure 1. ICS Problems by Category.

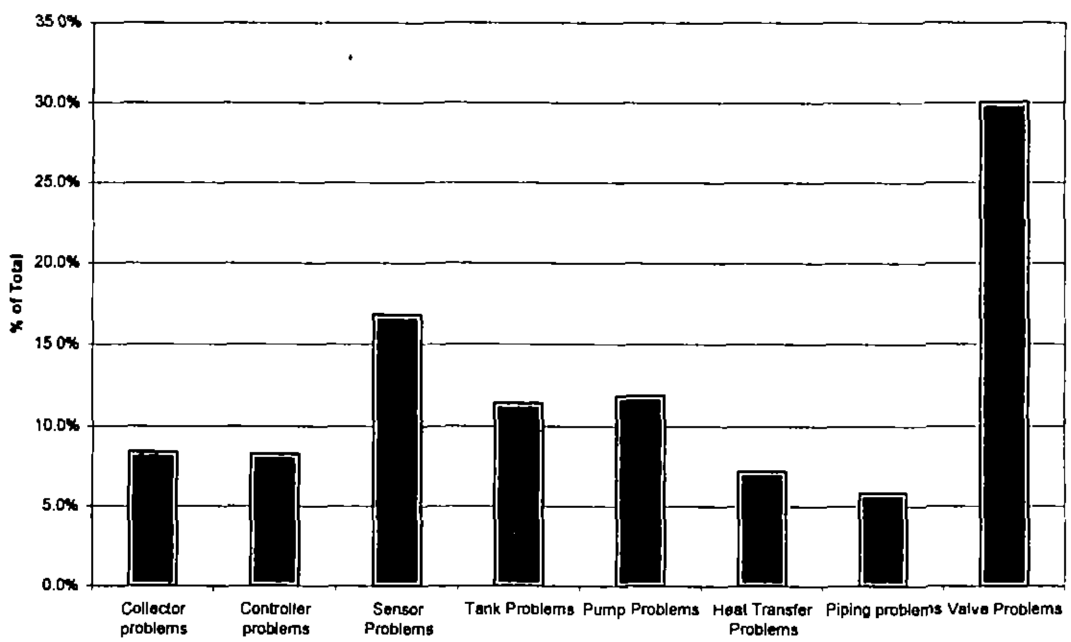


Figure 2. Pumped Systems Problems by Category.