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The Development of a Roof Integrated Solar Hot Water System

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The Development of a Roof Integrated Solar Hot Water System

Final Report

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Abstract

The Salt River Project (SRP), in conjunction with Sandia National Laboratories (SNL) and Energy Laboratories, Inc. (ELI), collaborated to develop, test, and evaluate an advanced solar water-heating product for new homes. SRP and SNL collaborated under a Department of Energy Cooperative Research and Development Agreement (CRADA), with ELI as SRP's industry partner. The project has resulted in the design and development of the Roof Integrated Thermal Siphon (RITH) system, an innovative product that features complete roof integration, a storage tank in the back of the collector and below the roofline, easy installation by homebuilders, and a low installed cost. SRP's market research guided the design, and the laboratory tests conducted at SNL provided information used to refine the design of field test units and indicated that the RITH concept is viable. ELI provided design and construction expertise and is currently configured to manufacture the units. This final report for the project provides all of the pertinent and available materials connected to the project including market research studies, the design features and development of the system, and the testing and evaluation conducted at SNL and at a model home test site in Phoenix, Arizona.

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ACRONYMS

CRADA	Cooperative Research and Development Agreement
DOE	Department of Energy
ELI	Energy Laboratories, Inc.
NSTTF	National Solar Thermal Test Facility
RITH	Roof Integrated Thermal Siphon
SNL	Sandia National Laboratories
SRCC	Solar Rating and Certification Corporation
SRP	Salt River Project
SWH	solar water heater
TDT	Technology Development Team

INTRODUCTION

Salt River Project (SRP), a public power utility in Phoenix, Arizona, in collaboration with Sandia National Laboratories (SNL) and Energy Laboratories, Inc. (ELI), developed, tested, and evaluated an advanced solar water-heating product for new homes. SNL and SRP collaborated under a US Department of Energy (DOE) Cooperative Research and Development Agreement (CRADA). ELI acted as the industry partner, which was aligned with SRP under a private agreement.

The project resulted in the design and development of an innovative solar water-heating product, called the Roof Integrated Thermal Siphon (RITH) system, for new home construction. The product's unique features include complete roof integration (like a skylight), a storage tank in the back of the collector and below the roofline, easy installation by homebuilders, and an installed target cost of \$1,500. SRP's market research, which quantified consumer requirements for a solar water-heating product, guided the design. This is the final report for the CRADA project and provides all of the pertinent and available materials connected to the project including market research studies, the design features of the RITH system, the development of RITH, the product's testing and evaluation at SNL and at a builder's model home test site in Phoenix, Arizona, and the Solar Rating Certification Corporation testing and certification.

BACKGROUND

SRP provides electrical services to over 700,000 customers in the Phoenix, Arizona, metropolitan area and has participated in or sponsored renewable energy technology activities since the early 1980s. The focus of these renewable technology activities has been on solar electric technologies. However, during the early 1990s, SRP, like many other electric utilities, began to consider the assessment and development of other renewable technologies and products, including solar water heating. This interest resulted in an SRP energy technologies portfolio that now includes solar water-heating and solar dish technologies, in addition to solar electric (primarily photovoltaics), landfill gas generation, fuel cells, and microturbines.

During the mid 1990s, with electric utility industry restructuring under way and increasing customer interest in green products, SRP began assessing such products and, as part of this process, decided to investigate opportunities in solar water heating. To do so, SRP conducted a market research assessment that suggested consumer interest in solar water heating and a potential solar water-heating market in SRP's service territory. However, the initial studies also showed numerous barriers to consumer acceptance of solar water-heating products.

DEVELOPMENT OF THE COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENT

SRP approached SNL to explore interest in jointly pursuing a project to overcome the barriers noted above. Initially, SNL agreed to provide some technical assistance to SRP in this endeavor. SNL's time would be funded by the DOE. A short time later, SNL agreed to work with SRP under a CRADA, which was to be 100% funds-in, to fund all of SNL's portion.

RESEARCH ACTIVITIES

SRP initiated the Solar Water Heating Project by determining consumer preferences using market research. This was then used to develop, test, and evaluate a solar water-heating product consistent with those needs and to assess the state of existing solar technology. The focus of the project was on solar water heating in new home construction. There is significant new home construction in SRP's service area and thus fertile ground for measuring initial customer interest.

The Solar Water Heating Project included the following activities:

- Market Research
- Technology Assessments
- New Product Concepts
- Proof of Concept
- Field Testing and Evaluation
- Certification by the Solar Rating and Certification Corporation (SRCC)

A description of each of the activities follows.

Market Research

SRP led a six-month market research study, using both focus groups and surveys, to meet three key objectives:

- (1) determine consumer preference for solar water heaters (SWHs) compared to other home upgrade options,
- (2) determine the features and attributes of SWHs that would maximize consumer interest and market potential, and
- (3) better understand how to market SWHs to particular consumer segments.

The key findings indicated that:

- SWHs have a negative reputation, but new solar technology attracts home buyers after they have been introduced to the new technology.
- The major perceived advantage to solar systems is reduced energy costs.
- As home options, SWHs were more popular than upgraded countertops, home security,

or fireplaces, but less popular than energy-efficient windows and appliances.

- Home buyers expect it to cost \$1,000 to \$1,500.
- Consumer preference is driven by system performance, where it is placed on the home, price, and backing by a reputable firm.
- Successful marketing of SWHs depends on a team of manufacturers, builders, realtors, and consumers.

Appendices A, B, and C contain the details of the market survey including how it was conducted, a summary of the data collected, and the final results and conclusions.

Appendix A is a study that was conducted by SRP, the National Renewable Energy Laboratory, and Symmetrics Marketing Corporation. It assessed the potential market for a solar hot water product in SRP's service territory. Appendix B contains the final report and a presentation of the results of a study by SRP and the National Association of Home Builders. Appendix C contains a presentation of a market study for Renewable Energy Programs conducted by SRP and Cambridge Systematics, Inc.

Technology Assessment

SRP decided to assess the potential for solar water-heating technology as a possible business opportunity and/or green product offering in its service territory. Working with SNL and ELI, SRP formed a Technology Development Team (TDT) to identify or develop a solar hot water technology that would be appropriate for their market area. Using the results of the research as a guide, the team outlined the attributes of a solar water-heating system that would be successful in the Phoenix market. The attributes included:

- Total system cost to the homeowner of \$1500 or less, including markups by the manufacturer, distributor, homebuilder, and associated contractors.
- Full roof integration. The system would be built into the roof, not placed on the roof (see Figure 1).
- Completely passive design. The system could not have moving parts.
- The system would resemble accepted home architectural features, such as roof windows or skylights – aesthetics were a primary requirement.
- The system should be leak-proof. Any leak resulting from system's operation must leak on the roof or otherwise be prevented from leaking into the home.
- The system should be freeze-resistant in areas of the southwest United States, particularly in the Phoenix, Arizona, area.
- The system should satisfy at least 50% of the hot water load in the home.
- The system should be installable by a plumber as part of the normal home construction. No specialty contractor should be required.



Figure 1. Conceptual design of RITH system.

The TDT used these attributes to screen commercially available products. The initial task was a survey of the solar water-heating industry and a detailed review of existing SWHs. The team concluded none of the commercially available products satisfied all the attributes identified by the market research. The requirements for full roof integration and potential to achieve the cost target were major obstacles for the existing products.

Given this conclusion, the TDT explored other options, including modifications to existing product designs or development of new product concepts. The objective was to develop a product concept meeting the attributes identified in the market research.

New Product Concept

In response, the TDT conducted an internal design competition in which each member could submit a concept or concepts to the remainder of the team. The conceptual package had to include engineering specifications, a bill of materials, and manufacturing cost estimates. The whole team evaluated each idea and voted on a single concept to pursue.

Several innovative concepts were presented, including modifications of existing products, such as integral collector systems. However, the team agreed the concept with the most potential was the one proposed by ELI. Called RITH, this Roof Integrated Thermal Siphon collector system meets all of the required market characteristics.

A thermosiphon solar system is one in which a tank is placed above the collector with a tube connecting the bottom of the tank to the inlet (bottom header) of the solar collector and the top of the tank is connected to the outlet (top header) of the solar collector. The system is pressurized by normal city water pressure (around 50 lb/square inch). As the solar radiation falls on the collector and heats the water it naturally rises, creating a natural flow through the collector and

the tank by the cooler water flowing into the bottom of the collector. The hottest fluid stratifies on the upper part of the tank.

The storage tank becomes a source of preheated water for the home's water-heating system. Cold water from the community supply system is fed into the bottom of the storage tank and warm water flows out of the top of the tank. This warm water is fed into the backup water heater. If the pre-heated water is sufficiently hot, the backup water heater will not fire, thus saving energy. Thus, all of the hot water used in the premises will pass first through the thermosiphon tank and then through the backup water heater.

The unique feature of RITH system is the placement of the tank underneath the collector, instead of above it, as in traditional thermosiphon systems. With the tank in this position, the static head pressure is reduced at typical new home roof pitch angles, 4/12 and 5/12 for the Phoenix area, which strongly affects the maximum achievable collector flow rate.

The reduced head pressure is partially compensated for by the increased temperature differential across the absorber. The high absorber temperature differential is realized by fabricating the absorber from copper fins coated with the solar selective material Black Crystal, manufactured by ELI. A solar selective material can readily absorb solar radiation but has limited reemittance.

There was much discussion on the optimum size of the water tank as well as its position relative to the collector. The 50-gallon (gal.) tank used in RITH 50 was a commercially manufactured steel tank glass lining normally used for a domestic electric water heater. Every tank used in a RITH system after the first one used a 70-gal. stainless steel tank manufactured by ELI by forming a cylinder using sheet metal and welding on commercially manufactured end caps. The tank in RITH 80 is lower than the later models. Testing showed the flow rate was rather low. To increase the flow rate the system had to be put at a 45° angle, which is not acceptable for a roof integrated system where the typical roof has a 5/12 pitch (22.6° angle) at most. Moving the tank farther up increased the thermosiphon flow rate to an acceptable level when at a standard 5/12 pitch.

The stainless steel tank is used in RITH reduces the system dry weight and has a long-term corrosion resistance. The tank and collector are contained in a structural framework that supports the unit, the collector assembly, the tank insulation, and the flashing for integration into the roof surface. RITH is enclosed in a one-piece watertight housing that captures any leaks from the system and diverts them to the roof. The system is freeze-resistant in mild climates through a reverse siphoning subsystem that slowly circulates warm water from the tank through the absorber at night.

The design team worked for several months to refine the design and to estimate the performance of the new system. Several thermal performance models were developed to aid in the detailed design of the RITH subsystems, including collector sizing, plumbing placement, and the temperature distribution in the tank. A simple economic model was also incorporated into the collector performance model to estimate the financial benefit of the product.

Appendix D contains reports of each TDT meeting.

Proof of Concept

Under contract to SRP, ELI constructed two prototype RITH systems. One system was designed to target two average families, both of which would be living in an all-electric home: a family of three and a family of four. The first prototype system consisted of a 50 gallon tank and a ~32 ft² absorber for a family of three. The second prototype consisted of an 80 gal. system envisioned for a family of four.

Both systems were sent to SNL for thermal testing at the National Solar Thermal Test Facility (NSTTF) at SNL. The team dubbed the first system “RITH 50.” The 50 gal. tank used in RITH 50 was a commercially manufactured steel tank with glass lining normally used for a domestic electric water heater. RITH 50 used a collector 48.5 in. wide and 89.375 in. long for an area of 2.79 m² (32 ft²).

RITH 50 was installed and tested on an azimuthal tracking, or rotating, test platform that allows the RITH system to be rotated such that the collector remains near normal to the sun (see Figure 2). This speeds up the test process by minimizing variations in solar positioning and maximizing the amount of isolation on the RITH unit during the day.



Figure 2. RITH 50 under test at SNL.

Both a serpentine and a parallel absorber configuration were evaluated on this first system as a function of collector tilt angle. The parallel absorber used two headers in the collectors, one at the top and one at the bottom. Riser tubes, each bonded to a metal fin absorber, are connected to the top and bottom header, allowing water to flow in parallel in the risers between the two headers while being heated by the sun in the process. Cool water is injected into the lower header and heated water is extracted from the top header.

The serpentine collector has no headers. It uses a single tube entering at the bottom of the collector and is bent in a serpentine fashion from one side to another with a spacing of about six inches until it reaches the top of the collector. The tube is bonded to a thin metal fin, which collects the energy from the sunlight and conducts it as heat into the serpentine tube. This collector array would consistently have outlet temperatures close to or over 100 °C due to the low thermosiphon flow rate, which caused vapor lock in the array.

Based upon the increased collector flow rate achievable at the shallow collector tilt angle requirements of either a 4/12 or 5/12 pitched roof, the parallel absorber configuration was selected as the collector configuration for future RITH systems.

The second RITH unit arrived about six months after the first and incorporated a larger parallel absorber (~40 ft²), the larger 80-gal. tank, and greater flexibility to easily reconfigure the plumbing configuration. It was dubbed “RITH 80.” Since the early testing of this unit took place during the summer months and other components were under test on the rotating platform, it was tested in a fixed configuration on the ground.

Both prototype RITH units were heavily instrumented to measure the input insolation, various absorber and tank temperatures, and the collector fluid flow rates. A typical day’s measured performance for the first RITH unit is shown in Figure 3.

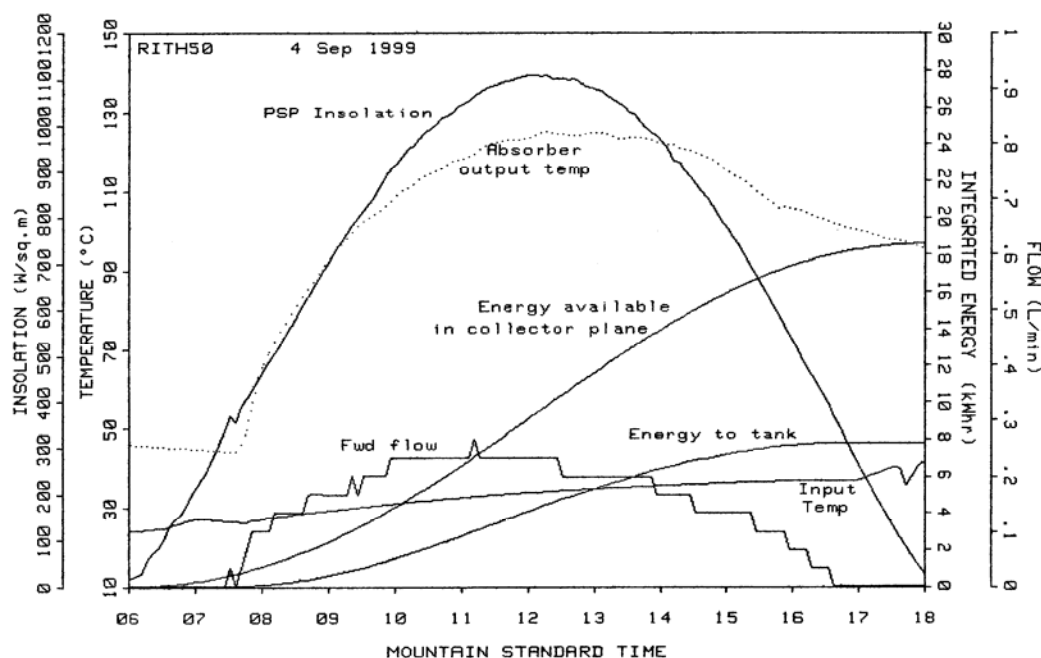


Figure 3. Typical measured performance of RITH 50 prototype with parallel absorber.

The thermal performance testing results enabled preliminary optimization of the system design parameters (i.e., tank/absorber placement, tank size, collector size, piping configuration, etc.). Thermosiphon flow rates (both forward and reverse), absorber temperature patterns, and tank temperature stratification were also investigated to maximize the RITH energy performance. These tests suggested the RITH performance is comparable to or better than most integral units and would be freeze-proof in the southwestern U.S. low-desert climates.

Based upon the testing results from both prototype units, the RITH thermal performance model was refined and used to aid in the design of the field prototype RITH unit for an SRP “average” family of four’s electric water heating load, shown in Figure 4.

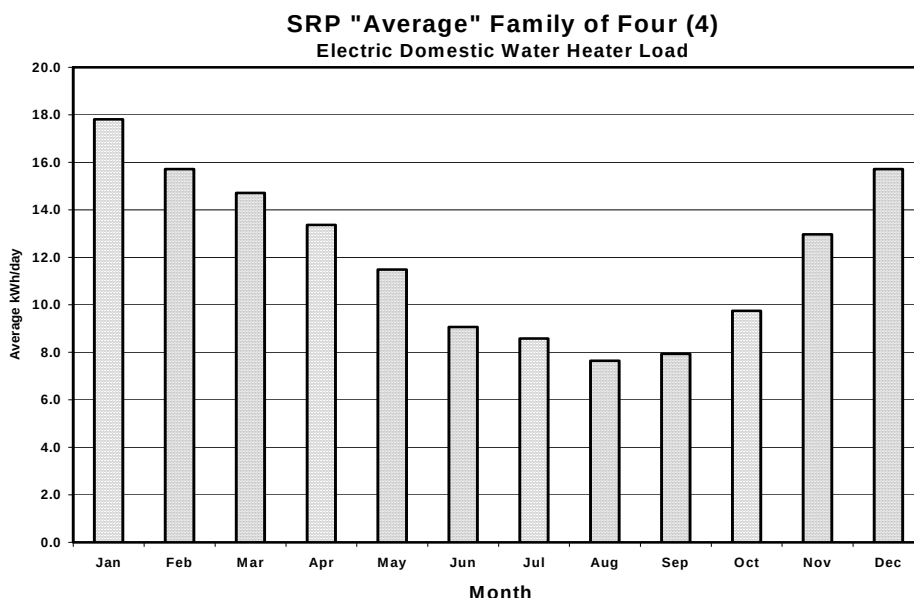


Figure 4. Typical hot water load for a family of four.

The performance model estimates the average monthly energy delivery and resulting solar fraction for the RITH unit with an absorber area of $\sim 32 \text{ ft}^2$ and a tank size of 70 gal. A plot of the model results is shown Figure 5.

Testing the RITHs showed how a minor part change can have a major impact on the operation of the system. For instance, the use of flex hoses to connect the storage tank to the collector made installation easy but decreased the efficiency of the system.

Another area of significant discussion was the configuration of the output of the collector to the inlet of the tank. Because of the low flow rates involved from being a thermosiphon system the water coming from the collector does not mix very well with the water in the tank. Water will stratify in temperature with very little mixing. If it is allowed to, the hot water going into the tank from the outlet of the collector will form a channel going straight to the top of the tank with very little mixing and very little temperature change. This will form very hot water at the top of the tank and cold water at the bottom. Because of this stratification, the tank will have maybe 10 gal. of very hot water at the top with the rest of the tank containing lukewarm water, which is not what is wanted.

Phoenix, AZ Average Insolation
For 4/12 Pitch Roof Plane Facing South
and Calc. RITH Solar Fraction

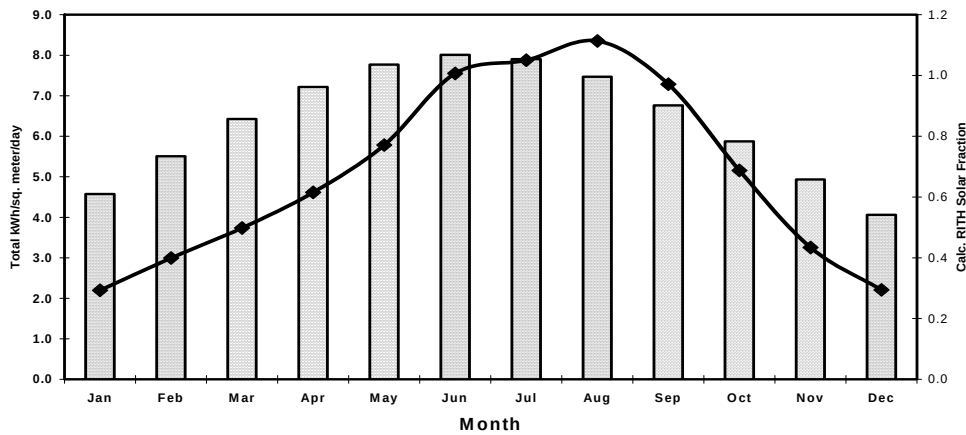


Figure 5. Average solar radiation in Phoenix on south-facing 4/12 roof and estimated solar fraction for a family of four.

A diffuser was designed to address this problem. It consists of a pipe capped at one end with holes along the side. Hot water from the collector flows into the uncapped end and the holes in the sides of the tube faces the bottom of the tank. This forces the hot water to mix more with the rest of the water in the tank. Appendix E contains pictures of all of the diffusers used in testing the various RITHs.

During the testing of RITH 50 and RITH 80 SNL developed a new process for attaching the fin with the solar selective coating to the riser tube. Attaching the fins to the riser using clips was deemed unreliable because of lifetime issues. Brazing the fins to the riser was too expensive. It was decided to develop a process to laser weld the fins to the riser tubes. A group in Germany working on the same problem developed a laser welding process where the laser beam is directed down on the fin area on top of the tube. They had a great deal of difficulty controlling the laser energy to weld the fin to the tube and not burn through the fin. They also had a problem of reflection off the fin back into the laser itself. In fact, they burned out one laser crystal before perfecting it. SNL's approach was to direct the laser beam between the fin and tube, as shown in Figures 6, 7, and 8.

Using this configuration, any deflection of the laser beam is directed farther down into the joint area and not back to the laser itself, thereby avoiding the problem the Germans had. The lack of reflection away from the piece also means there is more energy available for the welding of the two parts together, which means much lower initial laser energy is needed.



Figure 6. Test setup for welding fin to tube.



Figure 7. Laser welding of copper fin to riser tube.



Figure 8. Laser drive mechanism.

Basically laser welding is a spot welding process where spot weld after spot weld is made as the part is moved by the laser. The speed of the laser and the part moving past the laser determines the desired amount of overlap between spot welds. Every laser has an energy limit per unit time that is a combination of the energy of the pulse and the number of pulses per minute. Since this process uses less pulse energy for each spot weld, the number of pulses per minute can be increased without overloading the laser. Obviously, the greater the number of pulses per minute the faster a length of fin can be welded onto the riser tube. This translates directly to less time to weld a fin to a riser, which means in manufacturing mode more parts/hour or less cost per collector. The optimum speed of the part through the laser was determined to be 51 in./min. The laser technique developed by SNL was patented.¹ However, no CRADA funds were used for the development process and, therefore, the patent and the associated intellectual property remain solely with SNL.

The initial laser welding tests were done welding copper fin to copper tube. At first the laser welding of the copper fin to the copper riser tube was done in two-foot sections at a time. This was necessary in order to set all the parameters to consistently produce the proper welds. Because the riser tubes are much more than 2 feet in length, to completely weld a full-length riser tube for the collector required several setups, which is too labor-intensive for production. The test setup was changed, as shown in Figure 9, to allow the laser welder to weld the full length of the riser tube in one setup.



Figure 9. Riser tube and fin fed into the welder.

Later, RITH systems used copper fins and stainless steel risers and headers. The same welding technique was used to make essentially perfect welds of the copper fin to the stainless steel tubing. Appendix F contains more detailed information about the welding of the fin to the tube and the resulting thermal performance of this subsystem.

Field Testing and Evaluation

The team designed and fabricated four more prototype systems that were tested for two years on a new home residence. They were called RITH 3, RITH 4, RITH 5, and RITH 6. The purpose of this two-year field test was to determine RITH performance in a new home environment and to evaluate potential customer and builder reactions to this product. All of the RITH systems were tested at SNL before placing them in the field test environments. The field test objectives include the following:

- (1) Validate performance of RITH in a real home and measure actual energy savings. Loads are created to simulate various family situations (e.g., three-person morning load; five-person evening load).
- (2) Assess the ease of installation as well as the builder's and trades' reaction to the product.
- (3) Assess potential homeowner reaction to RITH as a home appliance.

SRP and the technology development team identified a number of requirements for the setting and field testing of RITH. These included:

- Installation in an all-electric home in SRP's territory; a builder's model home would be ideal.
- The home must have a south-facing roof with at least a 4/12 pitch. A steeper pitch will improve RITH performance.
- Installation over the garage area and near the hot water heater. The team wanted to minimize the risk of any potential leaks damaging the interior part of the home. Because the system is basically a preheat water system and the domestic water heater typically is

in the garage, the closer the solar unit is to the conventional hot water heater the greater the likelihood of minimizing heat losses in piping.

- Installation in a higher-end home; starter homes were not considered good candidates for the first RITH units.
- Align with a national—rather than regional—builder. SRP considered a national builder to be a long-term advantage in future marketing of the product.
- Home must be generally accessible to the RITH technology development team so that monitoring equipment could be maintained.
- RITH must be visible from the street.

The actual home identified for RITH 3 testing included most of these characteristics. It was a model built by Calnex Homes, a mid-sized local builder in the Phoenix area. The builder was a participant in SRP's energy conservation programs and keen to be part of testing the RITH unit.

The principal features of this test application on the Calnex Homes model home, located about 40 miles east of Phoenix, are:

- 4/12 roof pitch, south-facing, with no obstructions.
- It is a model home that will be unoccupied for at least one year, thus completely accessible to the testing team.
- It is an all-electric home located in SRP territory.
- RITH is visible from street.
- It has a regional builder.
- RITH is located over a bedroom, rather than the garage.

Although this particular application did not meet all of the specifications outlined above, it was deemed optimal considering the difficulties in identifying a perfect site and the great desire to begin testing as soon as possible.

The RITH 3 unit was installed on the Calnex model home in late October 2000.

The builder's subcontractors, under the supervision of SRP's technology development team, installed the system. The entire installation process was videotaped to determine success areas and possible problems.

Several positive outcomes resulted from this test. First, the builder and trades were enthusiastic and cooperative. Second, the builder showcased the unit to potential customers. Third, the system integrated well into the roof, and according to the builder and some of his sales representatives looked as good as (or better) than a roof window or skylight (see Figure 10). Fourth, other builders became interested in testing RITH.



Figure 10. RITH 3 on Calix home in Gold Canyon.

As a result of this effort, several important lessons were learned:

- RITH weighs 800 lb (dry weight) and a crane was needed to install it. Work is being done to reduce its weight by developing a lighter structural framework and using a stainless steel tank.
- The unit is hard to manipulate once it is in place because there are no handholds to allow the tradespeople to position it before it is secured in place. Handholds will be integrated into the next design.
- The roofer did not like the integration system because he was accustomed to a curb system, typical with skylights. The builder wants guaranteed leak protection. A secondary drip pan will be installed in the attic under each RITH unit (this is a typical code requirement for any conventional attic-mounted hot water heating system).
- The builder wanted an easy way to replace glazing. Currently, the design calls for the glazing to be caulked into the frame. A new framing and gasket system will be integrated into the next design.
- Truss modifications are needed to carry the water-charged weight of unit, about 800 lb (or $\sim 35 \text{ lb/ft}^2$). Truss modifications to carry additional roof weight are typically not problematic for builders, as long as they are planned. Therefore, detailed information about the RITH's weight will be provided to the builder with other system specifications.
- The distance between RITH and water heater is long (about 70 ft). The water line between the collector and backup water heater was heavily insulated to minimize heat loss in this long run of piping.

The SNL team developed a mathematical model of the RITH system and used it to predict performance of the system in its Phoenix location. Figure 11 shows the predicted solar fraction, which is the percentage of the hot water load that is met by the RITH system. Figure 12 shows the predicted energy delivery from the RITH system.

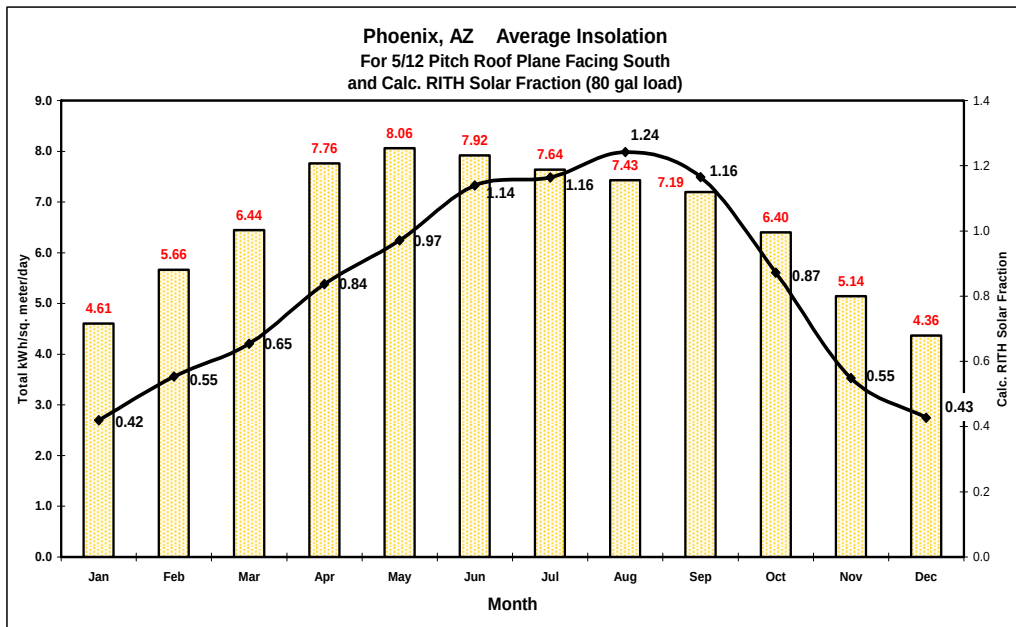


Figure 11. Predicted solar fraction for RITH system.

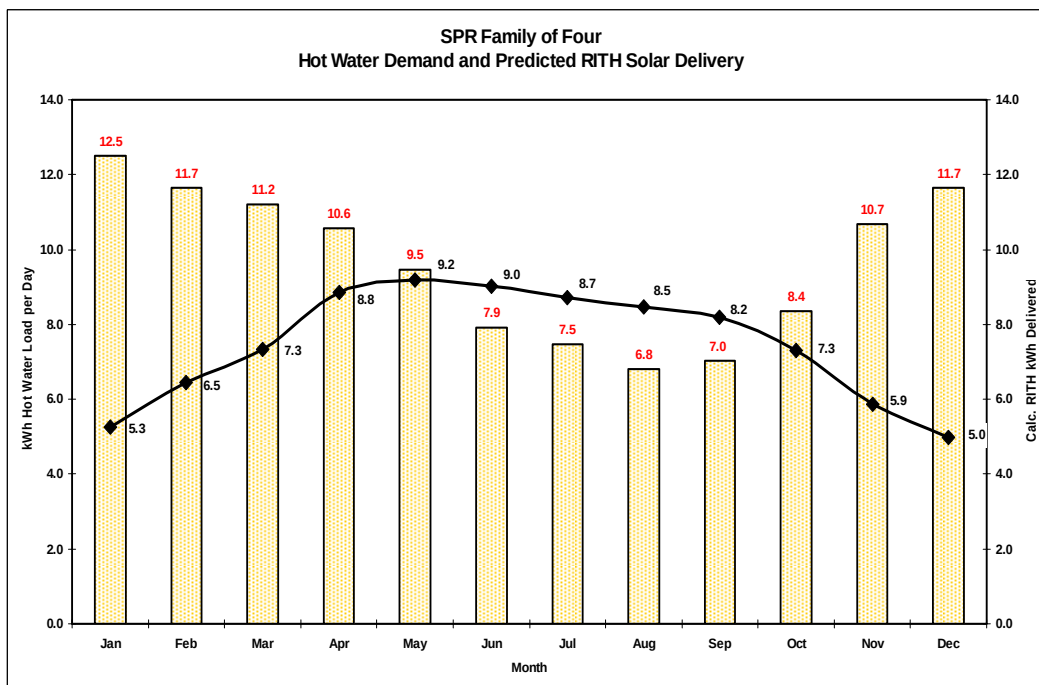


Figure 12. RITH predicted energy delivery from RITH system.

Since the RITH was installed in an unoccupied model home, no real hot water load exists. A hot water load was, therefore, created. SNL designed and built an automated hot water load generator using solenoid valves that open at periodic intervals to simulate the hot water load for a family of four. The monthly daily draw profile combines the SRP average family of four's electric water heating load and the standard 24-hour draw profile developed by the SRCC. Figure 13 shows how the RITH 3 field unit performed relative to predicted performance.

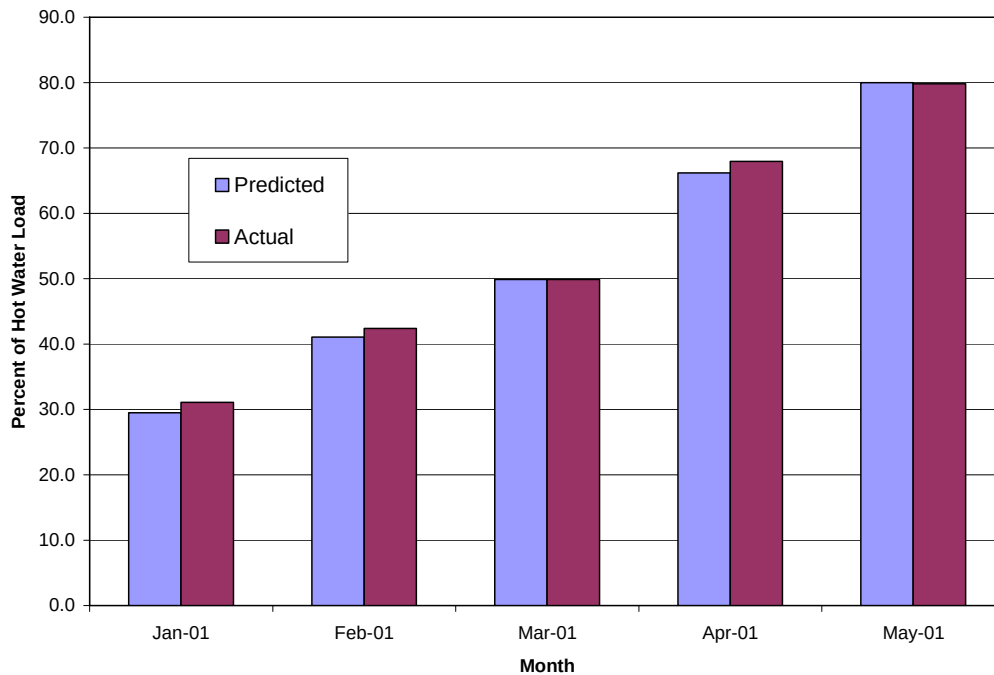


Figure 13. RITH 3 field unit predicted versus actual performance.

Appendix G contains details about the performance of the RITH 3 system.

The next two systems, RITH 4 and RITH 5, were installed in builders' display homes in the Phoenix area, as shown in Figure 14. A photovoltaic system was also installed on the roof behind RITH 5. RITH 5 was installed in a house similar to that for RITH 3 but notice how RITH 5 is above the garage, thus near the water heater, eliminating the long run of water line. RITH 3 required about 70 feet of plumbing to connect it to the domestic electric hot water heater, located in the garage, which as a result had an impact on its performance. RITH 5 was located on the roof of the garage and needed about 20 feet of plumbing to connect it to the domestic electric water heater. RITH 4 was also located in the garage near the water heater.

Appendix H contains detailed information about the results of testing RITH 4 and 5.

RITH 6 was tested at SNL and in its original configuration was identical to RITH 4 and 5. Later in testing it was changed into an all stainless steel design. RITH 6 was not tested in the field. Appendix I contains a summary of the results of the tests.



Figure 14. RITH 4 (left) and RITH 5 (right) installations.

Discussion Regarding the Design and Testing of RITH Systems

Testing the RITHs showed how a minor part change can have a major impact on the operation of the system. For instance, the use of flex hoses to connect the storage tank to the collector made it easier for installation since it did not require the use of a crane, but it decreased the efficiency of the system and the ease of initial operation. RITH 4 was installed as one whole unit and used bent tubing for connecting the tank to the collector. RITH 5 was installed as two units, the tank and collector, and used flex hoses to connect the tank to the collector.

RITH 6 started out with flex hoses and was later changed out with tubing. A flex hose has significantly higher flow losses than smooth wall tubing of the same diameter, which translates into lower flow through the collector, about 0.2 liter per minute (l/min) using flex hoses and about 0.35 l/min using tubing. It also makes it much more difficult for startup operation whenever the system is filled with water. When the system is filled with water after maintenance or for initial installation, air is entrapped in the system and forms bubbles that can block the flow in the collector. With the reduced flow rates of the system using flex hoses, it was very difficult to overcome the blockages formed by the air bubbles. For RITH 6, the fins in the collector had to heat up to about 130 °C to get enough thermosiphon force to force the air bubble out. When the flex hose was replaced with smooth wall tubing, startup was so easy it was almost as if the system had always been filled with water and the fin temperature was only 30 °C above the water temperature.

Removing air trapped in the solar water heating system was a major concern since, as discussed in the previous paragraph, any trapped air can cause the system not to operate. The first attempt at air removal was to use a commercially available air vent valve, which was used on RITH 3. Vent valves have been used for many years on solar systems and have an almost 100% chance of leaking within the first two years of service. The vent valve on RITH 3 started leaking within its first year of operation. With this history and experience it was highly desirable to not use vent valves.

The city water supply will also occasionally have air bubbles entrapped in it, which can also cause the system to not operate. A different kind of air eliminator was developed by ELI to remove any air trapped in the water. One made from copper is shown in Figure 15. The inlet to the system from the city water system is on the left side. The right side connects to the inlet of the tank for the solar system.

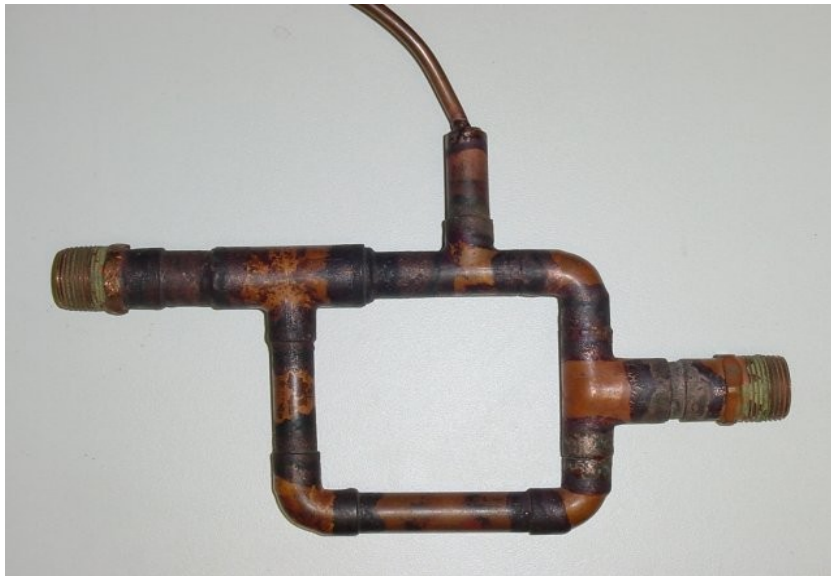


Figure 15. Copper air eliminator designed and built by ELI.

Another area of discussion was how to configure the inlet to the tank for the output of the collector to avoid temperature stratification. Because of the low flow rates involved, hot water going into the tank will go straight to the top of the tank with very little mixing while the cold water stays at the bottom. The result may be 10 gal. of very hot water in the tank with the rest lukewarm – not the desired outcome.

Several designs were tested in the RITH units. The diffuser used in RITH 80 was capped at the end and has holes drilled into the sides and was inserted such that the holes in the sides of the tube were facing the bottom of the tank. This forced the hot water to be distributed more into the rest of the water in the tank. The diffuser used in RITH 3 was not plugged at the end and did not have any holes drilled into the side. This design minimized the mixing of the incoming water from the collector outlet with the rest of the water in the tank. The diffuser in RITH 6 formed a tee with the ends of the tee capped and holes drilled into the side and inserted such that the holes faced the bottom of the tank. This was also the diffuser used for RITHs 4 and 5. Appendix E contains pictures of all the diffusers.

All the RITHs tested used copper tubing for the collector and interconnection tubing. After the initial design of the RITH was determined for the collector and tank size the team found that several areas in Arizona had city-supplied water that was corrosive to copper. In the Civano area the homes using copper tubing developed leaks in less than two years. The team decided to make all wettable parts of the solar water heater more corrosion-resistant to the water, and stainless steel, 304 or 316, was the natural choice. Basically, only the collector needed to be

changed since the tank was already stainless steel. The collector header tubes were changed from 1 in. tubing to 1 in. stainless steel tubing. The risers were changed from 3/4 in. copper tubing (0.875 in. outside diameter and 0.080 in. wall) to 5/8 in. outside diameter and 0.020 in. wall stainless steel tubing.

The collector went through a design change as well as several size changes. RITH 50 used a collector that was 48.5 in. wide and 89.375 in. long for an area of 2.79 m². RITH 50 was tested with two different absorbers. The first absorber tested used a serpentine collector where the inlet and outlet were the same tube that wound back and forth going up the collector. This collector array would consistently have outlet temperatures close to or over 100 °C due to the low thermosiphon flow rate, which would cause vapor lock in the array.

This collector was replaced with one using the current configuration of a larger-diameter header tube at the bottom and top of the collector and using smaller-diameter riser tubing connecting the two headers. This lowered the outlet temperature of the array and increased the flow rate through the array. RITH 80 had collectors that were 81.25 in. long and 43.75 in. wide for an area of 2.29 m². RITH 3 had a collector that was 84 in. long and 64 in. wide for an area of 2.85 m². After RITH 3 the size of the collector was fixed at 95 in. long and 45 in. wide for a collector area of 2.76 m². RITH 6 was tested with two different collectors, but the only difference was the first one used copper tubing, 1-in. headers and 3/4-in. risers, and the second one used stainless steel tubing, 1-in. headers and 5/8-in. risers.

Manufacturing Analysis

The team conducted a detailed analysis of the manufacturing of the RITH system. SNL and ELI developed the basic manufacturing approach. ELI provided a detailed list of materials and tooling needed to mass-produce the RITH system.

The introduction of all stainless steel components significantly complicated the manufacturing. For example, the creation of collector headers from a copper tube is a relatively simple process using a standard T-drill, which drills a hole and pulls out a wall of copper. This provides surface area to which the riser tubes can be brazed. This is a common practice in the solar industry. However, stainless steel is much harder than copper and a significantly more expensive T-drill is needed to do the same job.

There was no similar complication with the copper fins that were welded to the stainless steel riser tubes. SNL worked out the details to use the laser welder and the patented laser welding process to do this job.

The manufacturing process was studied closely by an independent team from SNL's Advanced Manufacturing Facility. The results are found in Appendix J and show that the proposed setup is sound and workable.

SRCC Certification

The RITH 6 system has completed certification testing by the SRCC. The results for the RITH 6 and the RITH system in Phoenix are found at the SRCC website (http://www.solar-rating.org/SUMMARY/Dirsum_20060822.pdf and <http://www.solar-rating.org/ratings/annuals/AZPHOENIX20060823.PDF>) and are also produced in Figures 16 and 17. Both figures show the first page of the website and the page with the information for ELI highlighted.



SUMMARY OF SRCC CERTIFIED SOLAR COLLECTOR AND WATER HEATING SYSTEM RATINGS

August 2006

Solar Rating and Certification Corporation
c/o FSEC, 1679 Clearlake Road
Cocoa, Florida 32922-5703
(321) 638-1537 Fax (321) 638-1010

Figure 16. Results of SRCC certification testing of RITH 6 (continued).

RATINGS SUMMARY OF OG-300 CERTIFIED SYSTEMS WITH ELECTRIC AUXILIARY

System Supplier	System Name	System Model Number	System Description	Cert Date	SEF	Q aux	Q par
Bobcat & Sun, Inc.	Sun-Pak	SP40CHE	Indirect Forced Circulation	9/8/1994	1.5	22785	6100
Bobcat & Sun, Inc.	Sun-Pak	SP80CHE	Indirect Forced Circulation	9/8/1994	2.5	10995	6078
Butler Sun Solutions	Solar Butler	BSS-S1-40Ea	Indirect Forced Circulation	7/1/2004	1.3	31950	1064
Butler Sun Solutions	Solar Butler	BSS-S1-40Eb	Indirect Forced Circulation	7/1/2004	1.2	36486	961
Butler Sun Solutions	Solar Butler	BSS-S1-50Ea	Indirect Forced Circulation	7/1/2004	1.4	29892	1008
Butler Sun Solutions	Solar Butler	BSS-S1-80Ea	Indirect Forced Circulation	7/1/2004	1.7	25095	1064
Butler Sun Solutions	Solar Butler	BSS-S1-80Ec	Indirect Forced Circulation	7/1/2004	1.4	30002	1002
Butler Sun Solutions	Solar Butler	BSS-S1-50Ec	Indirect Forced Circulation	7/1/2004	1.3	31209	1004
Butler Sun Solutions	Solar Butler	BSS-S1-40Ec	Indirect Forced Circulation	8/29/2005	1.4	30611	1004
Butler Sun Solutions	Solar Butler	BSS-PV1-40Ea	Indirect Forced Circulation	9/15/2005	1.3	32533	0
Butler Sun Solutions	Solar Butler	BSS-PV1-40Eb	Indirect Forced Circulation	9/15/2005	1.2	36810	0
Butler Sun Solutions	Solar Butler	BSS-PV1-50Ea	Indirect Forced Circulation	9/15/2005	1.4	30459	0
Butler Sun Solutions	Solar Butler	BSS-PV1-80Ea	Indirect Forced Circulation	9/15/2005	1.7	26179	0
Butler Sun Solutions	Solar Butler	BSS-PV1-80Ec	Indirect Forced Circulation	9/15/2005	1.4	30724	0
Butler Sun Solutions	Solar Butler	BSS-PV1-50Ec	Indirect Forced Circulation	9/15/2005	1.4	31776	0
Butler Sun Solutions	Solar Butler	BSS-PV1-40Ec	Indirect Forced Circulation	9/15/2005	1.4	31183	0
Butler Sun Solutions	Solar Butler	BSS-S1-80E2a	Indirect Forced Circulation	9/15/2005	1.5	28597	1242
Butler Sun Solutions	Solar Butler	BSS-S1-80E2b	Indirect Forced Circulation	9/15/2005	1.4	30642	1242
Butler Sun Solutions	Solar Butler	BSS-PV1-80E2a	Indirect Forced Circulation	9/15/2005	1.5	29609	0
Butler Sun Solutions	Solar Butler	BSS-PV1-80E2b	Indirect Forced Circulation	9/15/2005	1.7	26162	0
Energy Laboratories, Inc.	Roof Integrated Thermosiphon System	RITH 72 E	Direct Thermosyphon	8/18/2006	1.8	24363	0
Heliodyne, Inc.	Helio-Flo	HF 1408 G 80 AC S E	Direct Forced Circulation	10/25/2004	2.3	18055	1145
Heliodyne, Inc.	Helio-Flo	HF 1410 G 80 AC S E	Direct Forced Circulation	10/25/2004	2.8	14458	1145
Heliodyne, Inc.	Helio-Flo	HF 1410 G 120 AC S E	Direct Forced Circulation	10/25/2004	2.7	14776	1145
Heliodyne, Inc.	Helio-Flo	HF 23366 G 80 AC S E	Direct Forced Circulation	10/25/2004	5.2	7245	1145
Heliodyne, Inc.	Helio-Flo	HF 2408 G 80 AC S E	Direct Forced Circulation	10/25/2004	10.5	3009	1117
Heliodyne, Inc.	Helio-Flo	HF 2408 G 120 AC S E	Direct Forced Circulation	10/25/2004	37.8	0	1145
Heliodyne, Inc.	Helio-Flo	HF 2410 G 120 AC S E	Direct Forced Circulation	10/25/2004	41.8	0	1037
Heliodyne, Inc.	Helio-Flo	HF 3408 G 120 AC S E	Direct Forced Circulation	10/25/2004	16.5	0	2621
Heliodyne, Inc.	Helio-Flo	HF 3410 G 160 AC S E	Direct Forced Circulation	10/25/2004	16.5	0	2621
Heliodyne, Inc.	Helio-Flo	HF 1410 G 80 AC D E	Direct Forced Circulation	10/25/2004	2.2	18892	1145
Heliodyne, Inc.	Helio-Flo	HF 23366 G 80 AC D E	Direct Forced Circulation	10/25/2004	2.9	13872	1145

August 2006

Certification must be renewed annually. For current status contact:

SOLAR RATING & CERTIFICATION CORPORATION

c/o FSEC ♦ 1679 Clearlake Road ♦ Cocoa, FL 32922 ♦ (321) 638-1537 ♦ Fax (321) 638-1010

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Figure 16. Results of SRCC certification testing of RITH 6 (concluded).



**ANNUAL PERFORMANCE
OF
OG-300 CERTIFIED SYSTEMS
IN
PHOENIX, ARIZONA**

August 2006

Solar Rating and Certification Corporation
c/o FSEC, 1679 Clearlake Road
Cocoa, FL 32922-5703
(321) 638-1537 (321) 638-1010 Fax

Figure 17. Results of SRCC certification testing of RITH system in Phoenix (continued).

System Name	System Model	System Number	FTL (°F)	Energy Savings* (kWhr)	Comments
Energy Laboratories, Inc.					
Roof Integrated Thermosiphon Sy	RITH 72 E	2004006A	22	2600	
Heliodyne, Inc.					
Helio-Flo	HF 1408 G 80 AC S E	2001023A	27	3000	
Helio-Flo	HF 1410 G 120 AC S E	2001023C	27	3200	
Helio-Flo	HF 1410 G 80 AC D E	2001024A	27	2900	
Helio-Flo	HF 1410 G 80 AC S E	2001023B	27	3100	
Helio-Flo	HF 23366 G 80 AC D E	2001024B	27	3000	
Helio-Flo	HF 23366 G 80 AC S E	2001023D	27	3200	
Helio-Flo	HF 2408 G 120 AC D E	2001024D	27	3100	
Helio-Flo	HF 2408 G 120 AC S E	2001023F	27	3300	
Helio-Flo	HF 2408 G 80 AC D E	2001024C	27	3100	
Helio-Flo	HF 2408 G 80 AC S E	2001023E	27	3200	
Helio-Flo	HF 2410 G 120 AC D E	2001024E	27	3100	
Helio-Flo	HF 2410 G 120 AC S E	2001023G	27	3300	
Helio-Flo	HF 3408 G 120 AC D E	2001024F	27	3000	
Helio-Flo	HF 3408 G 120 AC S E	2001023H	27	3200	
Helio-Flo	HF 3410 G 120 AC D E	2001024G	27	3100	
Helio-Flo	HF 3410 G 160 AC S E	2001023I	27	3200	
Heliopak	16 DWCL HP 1 308 G 65 ACD	1992013E	-60	2000	
Heliopak	16 DWCL HP 1 3366 G 50 ACS	1992010J	-60	2400	
Heliopak	16 DWCL HP 1 3366 G 80 ACD	1992013G	-60	2200	
Heliopak	16 DWCL HP 1 3366 G 80 ACS	1992010K	-60	2500	
Heliopak	16 DWCL HP 1 408 G 65 ACD	1992013F	-60	2400	
Heliopak	16 DWCL HP 1 408 G 65 ACS	1992010A	-60	2600	
Heliopak	16 DWCL HP 1 408 G 65 PVD	1996004C	-60	2700	
Heliopak	16 DWCL HP 1 408 G 65 PVS	1996003C	-60	2900	
Heliopak	16 DWCL HP 1 408 G 80 ACD	1992013I	-60	2400	
Heliopak	16 DWCL HP 1 408 G 80 ACS	1992010N	-60	2600	
Heliopak	16 DWCL HP 1 410 G 65 ACD	1992013A	-60	2600	

*** A conventional 50 gallon electric water heater would consume 3500 kWh under these rating conditions.**

Prepared for Phoenix, Arizona by:
SOLAR RATING & CERTIFICATION CORPORATION
c/o FSEC ♦ 1679 Clearlake Road ♦ Cocoa, FL 32922 ♦ (321) 638-1537 ♦ Fax (321) 638-1010

Wednesday, August 23, 2006

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Figure 17. Results of SRCC certification testing of RITH system in Phoenix (concluded).

ELI plans to market and sell this RITH unit but may introduce a copper version of RITH first. The design of this system will be similar to RITH 5 and will have to undergo SRCC certification.

SUMMARY

The Solar Water Heating Project has developed a unique and innovative product concept, the RITH system. The testing and evaluation activities under way have validated its performance and provided insights on long-term reliability. RITH product development fostered a collaborative relationship between consumer research and traditional research and development protocol in the earliest stages.

The RITH system is a new and unique product that is responsive to the needs of the consumer. The RITH design is predicated on the criteria defined by market-focused research. The project has followed a structured process to determine if RITH is an acceptable solar water heater for the new-home market. Through a carefully designed test and evaluation program, RITH was tested in both laboratory and field environments. Through this process, a product design has emerged closely meeting all of the specifications outlined in SRP's market study. The laboratory tests conducted at SNL's NSTTF provided information used to refine the design of field test units responsive to SRP's consumer needs and indicated the RITH concept is viable. The results to date suggest the prototype RITH is performing as designed. Field testing continues to provide data to characterize the performance and operations over a range of residential water-heating requirements.

REFERENCE

1. Fuerschbach, P.W., A.R. Mahoney, and J.O. Milewski, Method for Laser Welding a Fin and a Tube, Patent #6,300,591.

**Appendix A.
Market Study of Solar Hot Water System
in Salt River Project Service Territory
Presentation of Final Results**

**Salt River Project (SRP), National Renewable Energy Laboratory (NREL),
and Symmetrics Marketing Corporation**

**SRP/NREL New Home Buyer
Solar Water Heater Trade-off Study**

Summary Report for Public Release

SYMMETRICS MARKETING CORPORATION

June 1998

SRP/NREL New Home Buyer Solar Water Heater Trade-off Study

Comprehensive Management Report



SYMMETRICS MARKETING CORPORATION

June 1998

New Home Buyer Solar Water Heater Trade-off Study
SRP/NREL Proprietary and Confidential

Background & Purpose

- ◆ A solar water heater is but one of several features that a buyer might look for in a new home. Budget limitations usually force buyers to make tradeoff decisions among features in order to keep the price of the home within their range. To the extent the desired bundle of features proves affordable, the buyer is more inclined to buy the house.
- ◆ This research is intended to calibrate the relative “utility” or importance of the solar water heater vis-a-vis other housing features in new home buyer decision-making. It is also intended to uncover the demographic and psychographic characteristics of new home buyers that are most correlated with the perceived utility of the solar water heater. In addition, the study will examine which features of the solar water heater, itself, are most valued by new home buyers when making home buying decisions.

Research Objectives

- ◆ The main objective of this study was to conduct quantitative marketing research targeted at new home buyers in order to guide product design and marketing strategies for solar water heaters. The specific research objectives were as follows:
 - To determine the relative utility (preference) of solar water heaters as compared to other home upgrade options
 - To determine the features and attributes of solar water heaters that would maximize consumer interest and market penetration
 - To better understand how to market solar water heaters to particular consumer segments by examining the demographic and/or psychographic correlates of solar water heater purchase interest

Methodology Overview

- ◆ Face-to-face interviews were conducted with individuals or couples (decision-making units or DMUs) who had purchased a new home within the past 24 months.
 - 200 interviews in Phoenix
 - 100 with homes \$100K - \$150K (referred to in this report as Phoenix Low-End)
 - 100 with homes \$150K - \$200K (referred to in this report as Phoenix Hi-End)
 - 100 interviews in Las Vegas
 - All with homes \$100K - \$150K
 - 35% individuals, 65% couples
- ◆ Pretest conducted in Phoenix to test and refine the research methodology
- ◆ Interviews conducted between March 5 and March 23, 1998

Methodology (cont'd)

- ◆ Lists of recent home buyers (past 24 months) were obtained from list brokers in the Phoenix and Las Vegas markets. Recent home buyers were then contacted by telephone and screened for eligibility.
 - decision-maker in home purchase past 24 months
 - bought home in desired price range
 - joint decision-maker invited to participate as well
 - security screening (no utility employees or market researchers)
 - does not currently own a solar water heater (Of those who participated in the study, 24 of the DMUs (8%) had had a solar water heater in a previous home.)
 - excluded those “extremely unlikely” to purchase solar
- ◆ Qualified participants were invited to a focus group facility for a face-to-face interview and were offered a \$50 incentive to participate.

Research Design Process

- ◆ The study design for this project was developed and refined by a team of individuals from several organizations. The core team consisted of individuals from Symmetrics Marketing, SRP, NREL and Sandia Labs. This team worked together on all major design issues including:
 - deciding on the markets (Phoenix and Las Vegas) and the price points for recent home buyers
 - deciding on what the trade-off/conjoint exercises would be
 - determining which home upgrade options would be included in the pairwise trade-off
 - determining the six major solar water heater features for the product design conjoint exercise (e.g., Price, Performance, etc.)
 - determining the attribute levels within each of the major features (e.g., \$1,000, \$2,000, \$3,000)
 - reviewing all study materials including product descriptions
- ◆ In addition to the core team members, input was also solicited from individuals at the National Association of Home Builders

Markets and Price Points

- ◆ **Markets:** The primary market for this solar water heater research was Phoenix given the particular interests of SRP. Co-sponsorship by NREL, however, allowed for the inclusion of a second market. While a number of markets were considered, including Sacramento and Southern California, Las Vegas was chosen by NREL because of its hot, sunny climate (similar to Phoenix) and its explosive growth and home building activity.
- ◆ **Price Points:** The participation of NREL in the study also allowed for the testing of differences in consumer preferences in two different home price ranges. While several price ranges were considered, the team decided to conduct 200 interviews in the \$100,000-\$150,000 range (split between Phoenix and Las Vegas) and 100 interviews in the \$150,000-\$200,000 price range (Phoenix only). This decision was made based on the number of homes built in these price ranges in these markets. While a higher-end luxury home price point was considered, the team decided to conduct this initial research in the larger, mass market. Well over half of the homes built in these markets fall within the selected price ranges.



New Home Buyer Solar Water Heater Trade-off Study
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Pretesting

- ◆ Once the design was finalized and the study materials were produced, Symmetrics conducted a pretest on March 2 with 1 individual and 4 couples at a focus group facility in Phoenix. Each decision-making unit (DMU) completed both the conjoint “card sort” exercise and the pairwise trade-off of home upgrade options. Following these research tasks, the interviewer de-briefed the participants regarding the ease and understandability of the research tasks.
- ◆ Following the pretest, several changes were made to the research tasks to make them clearer and less burdensome for the participants. In addition, changes were made to the conjoint card sort exercise so that the research information would be more actionable from a product design standpoint. These changes are discussed later in this report in the section concerned with the conjoint task.



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Study Tasks

- ◆ Research participants completed several survey tasks during the hour they spent at the research facility. In addition to the conjoint and trade-off tasks, home buyers completed self-administered questionnaires both before and after these exercises.
- ◆ Pre-measures -- before exposure to new solar water heaters
 - Household demographics
 - Purchase intentions (solar water heater and other home upgrades)
 - Personal demographics and environmental attitudes
- ◆ Conjoint exercise
 - Sorting and ranking of 27 solar water heater profiles
- ◆ Pair-wise trade-off
 - 21 pairs of home upgrade options, including solar water heaters and \$2000 discount
- ◆ Post-measures -- after exposure
 - Purchase intentions and changes due to exposure



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Research Questions

- ◆ The detailed findings of this study are divided into the major Research Questions that were addressed.
 - ① What is the level of consumer interest in new solar water heater products in relation to other popular home upgrade options offered by builders?
 - ② What is the perceived monetary value of solar water heaters relative to other home upgrade options?
 - ③ What are the optimal solar water heater designs taking into consideration consumer preference and product feasibility?



New Home Buyer Solar Water Heater Trade-off Study
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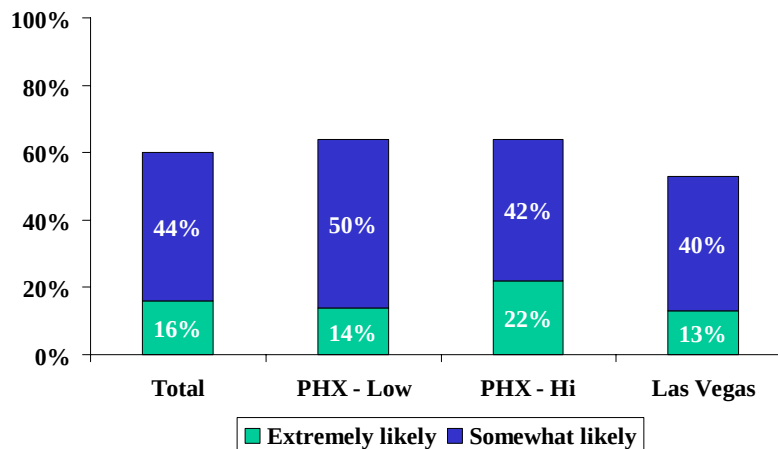
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Research Question #1

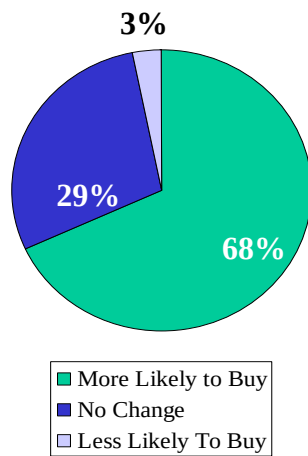
- ◆ What is the level of consumer interest in new solar water heater products in relation to other popular home upgrade options offered by builders?
- ◆ Method used
 - Purchase intention questions -- solar water heater plus five other upgrade options
 - Pre/post-measures
 - Pairwise trade-off exercise
 - Six upgrade options and an option to receive \$2000 discount off sales price

Likely to Buy Solar Water Heaters: Before

Overall, 60% of the home buyers said they were extremely/somewhat likely to buy a solar water heater before they were exposed to a description and pictures of newer solar panel technologies. The differences across the markets were not statistically significant.



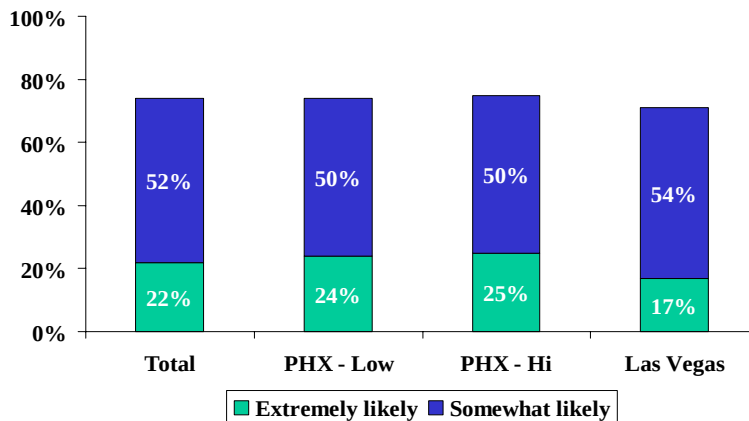
Change in Interest in Solar Water Heaters



- ♦ At the end of the interview session, study participants were asked to complete a final questionnaire. One question asked them to rate express their purchase interest in the six tested home upgrade options, including solar water heaters.
- ♦ Most respondents were impressed by what they learned about solar water heaters in the study and were more likely to purchase after the study.
- ♦ Levels of interest were similar across markets and price points.

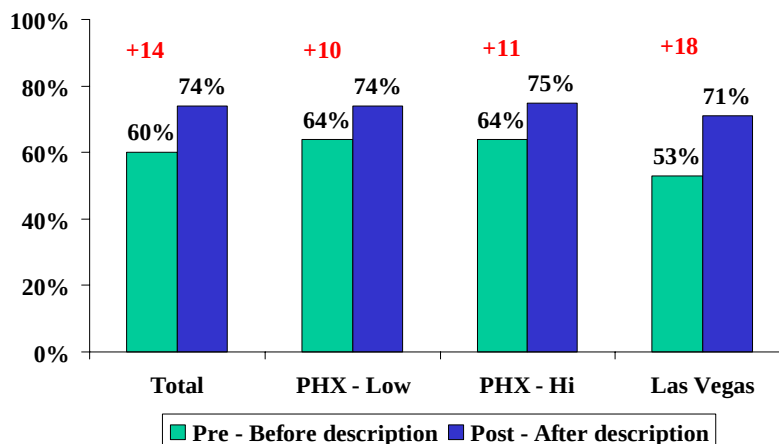
Likely to Buy Solar Water Heaters: After

The post-measures indicated a substantial increase in interest following the new product description. 74% of the home buyers claimed they would be extremely/somewhat likely to buy a solar water heater. While this increase was largely the result of focusing on solar during the session, it does suggest that home buyer education could significantly increase product interest.



Interest in Solar Water Heaters: Pre/Post

% Extremely/Somewhat Likely to Purchase



New Home Buyer Solar Water Heater Trade-off Study
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Solar versus Other Upgrades

- ◆ In addition to asking home buyers to rate their likelihood of purchasing a solar water heater, the pre-post surveys also asked their ratings of several other home upgrade options. The most popular upgrade options were upgraded, energy efficient windows and appliances.
- ◆ Prior to seeing the new solar panels, home buyers tended to prefer custom countertops over solar water heaters. Exposure to the new solar panels increased their interest in solar, particularly in relation to upgraded kitchen countertops.
- ◆ The most popular upgrades were ones that had the potential for direct cost savings for the consumer (energy-efficient windows and appliances and solar water heater). The upgrade options that were of least interest to these recent home buyers were home security systems and fireplace with blower kit.

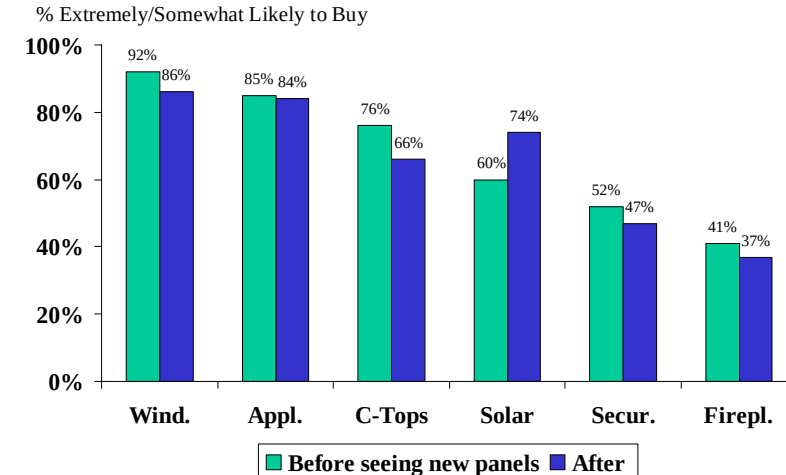


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Home Upgrade Options: Total Sample

- After seeing and hearing about the new solar technology, consumer interest in solar increased while interest in upgraded kitchen countertops declined.



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Home Upgrade Options: Pairwise Trade-off

- ◆ A second method for examining consumer preference for solar water heaters versus other home upgrade options utilized a **pairwise trade-off** technique.
- ◆ Respondents asked to indicate their preference across each pair of home upgrade options by assigning “points” to each (total of 100 points per pair). The following new home upgrade options were assessed:
 - Home security system
 - Upgraded appliances
 - Upgraded countertops
 - Upgraded, energy efficient windows
 - Fireplace with blower kit
 - Solar water heater
- ◆ Participants were also asked to trade-off a \$2,000 savings off the sale price of the home. Thus, instead of choosing the upgrade option, they could elect to reduce the sales price by \$2,000.

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Pairwise Trade-off Example

- ◆ The following illustrates how the pairwise trade-off task was introduced to study participants. The example below shows 3 of the 21 pairs of options that were presented to study participants.

For each pair of upgrade options shown below, indicate which you would prefer by dividing 100 points across the two options. You can use any 2 numbers that add up to 100. Remember the more you like an option, the more points you'd give that option.

Would you prefer ...

1. Upgraded windows _____pts. OR Upgraded appliances _____pts. = 100pts.
2. Home security system _____pts. OR A \$2,000 discount _____pts. = 100pts.
3. Upgraded countertops _____pts. OR Solar water heater _____pts. = 100pts.



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Home Buyer Preferences

- ◆ Overall, home buyers were most likely to want the \$2,000 reduction in the sales price of the home. The average probability of selecting the \$2,000 discount was .23, meaning that, on average, the \$2,000 discount was selected 23% of the time.
- ◆ Beyond the \$2,000 discount, preference for the upgrade options was rank-ordered in a way that was consistent with the post-measure purchase interest ratings. Hi-performance, energy efficient windows was rated highest among the six options (.18) -- followed by energy-efficient appliances (.16) and solar water heaters (.15).
- ◆ The solar water heater in the pairwise trade-off was preferred over upgraded kitchen countertops, home security and fireplace with blower kit.

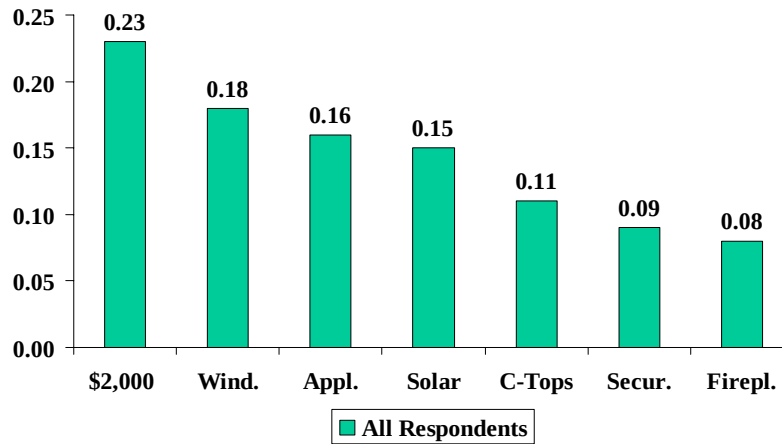


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Home Upgrade Options: All Respondents

Probability of Selection



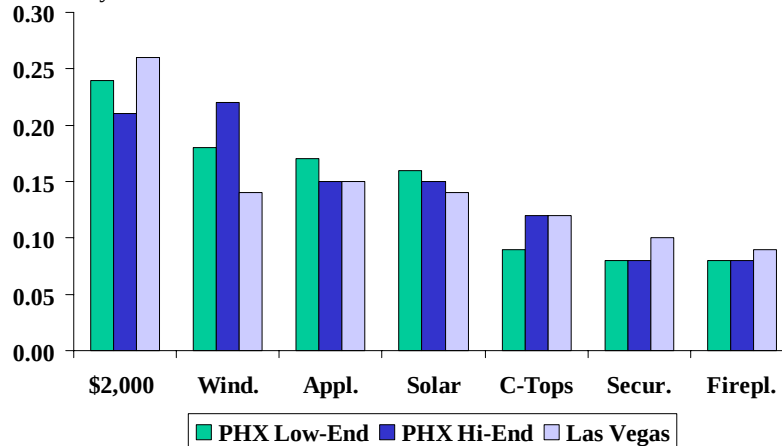
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Home Upgrade Options: Markets

- Interest in solar was similar across markets. The Hi-End Phoenix market tended to be more interested in upgraded windows, while the Las Vegas market was particularly money-conscious.

Probability of Selection



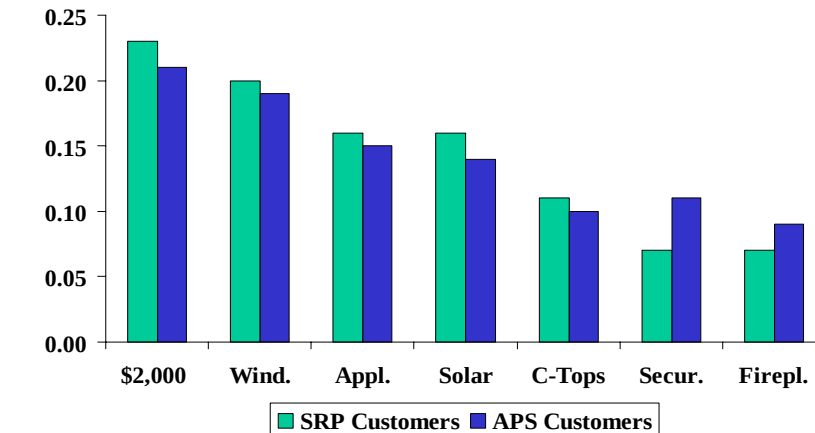
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Home Upgrade Options: SRP vs. APS

- There were no significant differences between APS and SRP customers in terms of their interest in solar water heaters. APS customers were more likely to be interested in home security than SRP customers.

Probability of Selection



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Interest in Solar: Demographic Correlates

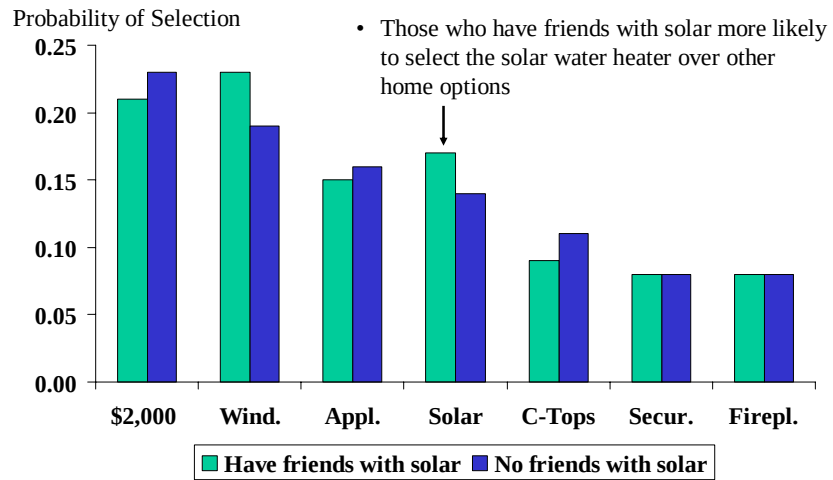
- ◆ Several analyses were conducted to determine the extent to which certain demographic groups were more likely than others to prefer solar water heaters. Respondents more likely to be interested in solar included people ...
 - in larger homes
 - who have friends/relatives with solar water heaters
 - who are more environmentally-conscious
- ◆ Although *current* owners of solar water heaters were not included in the study, those who had a solar water heater in a *previous* home were more likely to be interested in the new solar technology than home owners with no previous solar water heater experience.
 - This finding suggests that home owners with previous experience with solar water heaters would be a good target market for the new technology. This appears to be consistent with focus group findings which indicated favorable opinions of solar among current owners of solar water heaters.



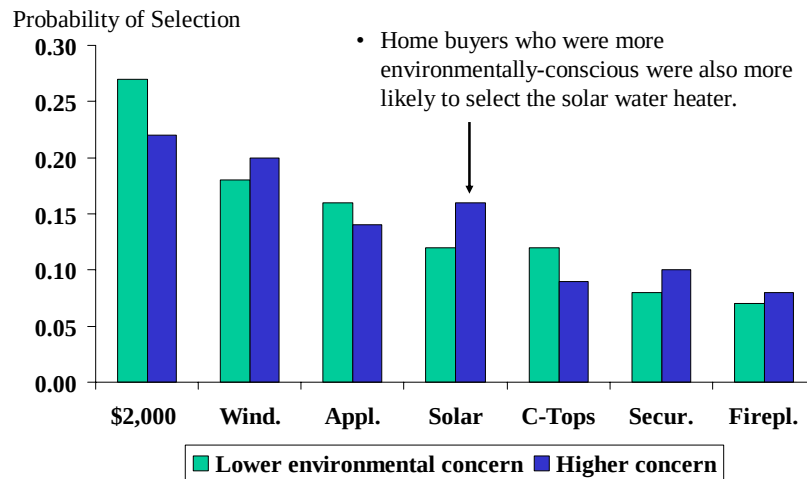
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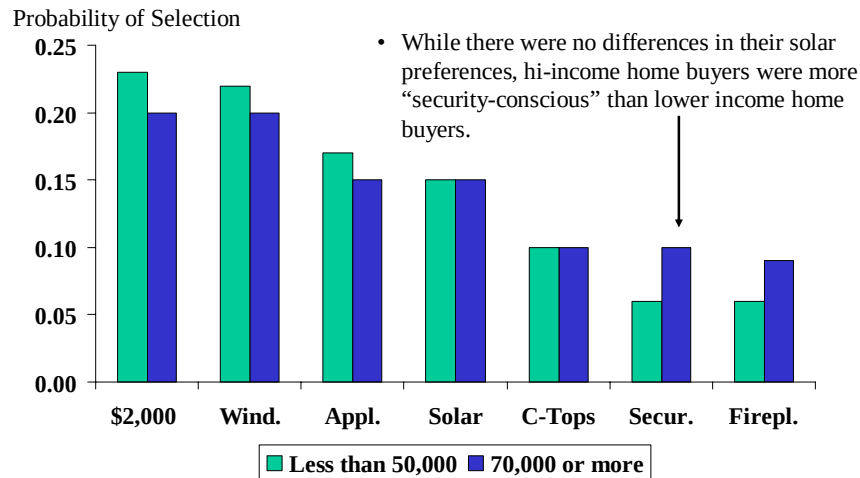
Home Upgrade Options: Friends with Solar



Home Upgrade Options: Environment



Home Upgrade Options: Household Income



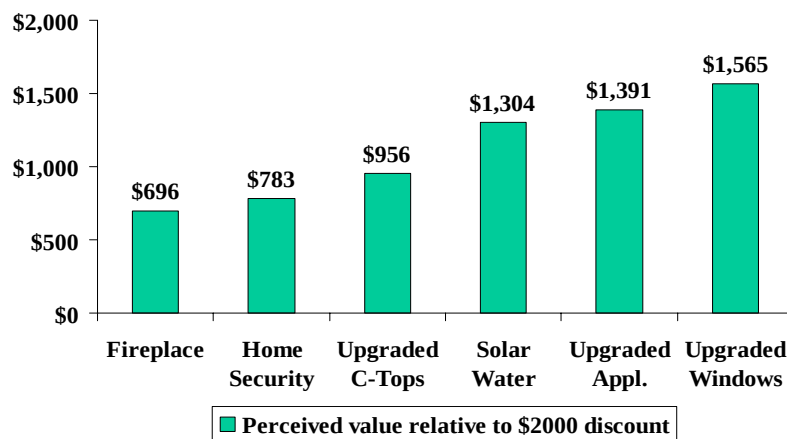
Research Question #2

- ◆ What is the perceived monetary value of solar water heaters relative to other home upgrade options?
- ◆ Method used
 - The pairwise trade-off allows for estimating the perceived value of the various home upgrade options relative to the \$2,000 discount off the sales price of the home.
 - Value was calculated by taking the ratio of the probabilities and multiplying that ratio by \$2,000.
 - For example, the ratio of the probability of selecting the solar water heater versus the \$2,000 discount is:
 - $.15/.23 = .652$
 - $.652 \times \$2,000 = \$1,304$ (the perceived value of a solar water heater relative to the \$2,000 discount)

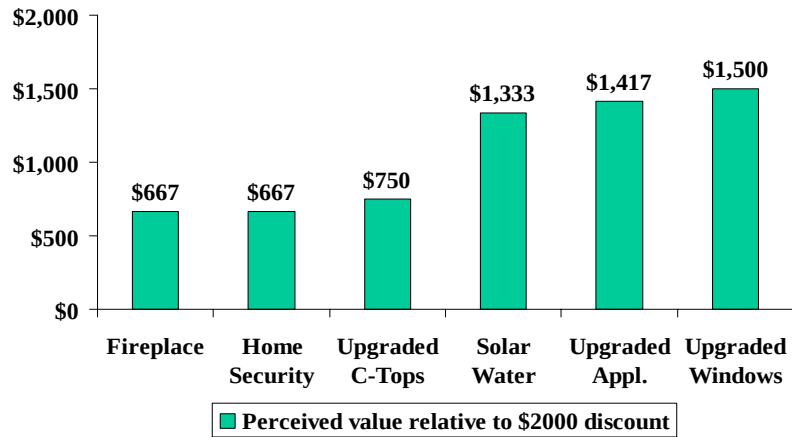
Perceived Value of Options

- ◆ The trade-off results suggested that consumers may not be willing to spend \$2,000 or more for a solar water heater. In the pairwise trade-off analysis, home buyers were much more likely to opt for a \$2,000 savings off the home price than to select the solar water heater.
- ◆ In the charts that follow, the perceived value of the solar water heater relative to the other home upgrade options is shown for the total sample of home buyers in the study as well as for the three main subgroups. For the total sample, the value of the solar water heater was in the \$1300 range. This is consistent with the conjoint profiles which demonstrated a desired price in the \$1000-\$1500 range.
- ◆ The perceived value of a solar water heater was highest in the Phoenix hi-end segment (\$1,429) and lowest in Las Vegas (\$1,077).

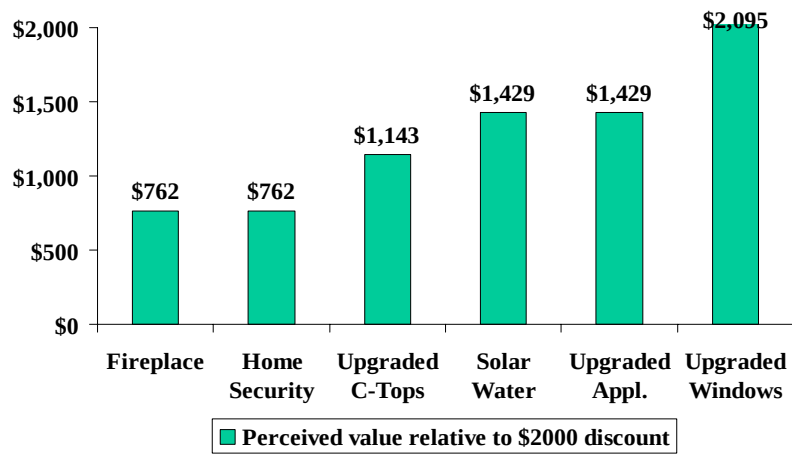
Perceived Value: Total Sample



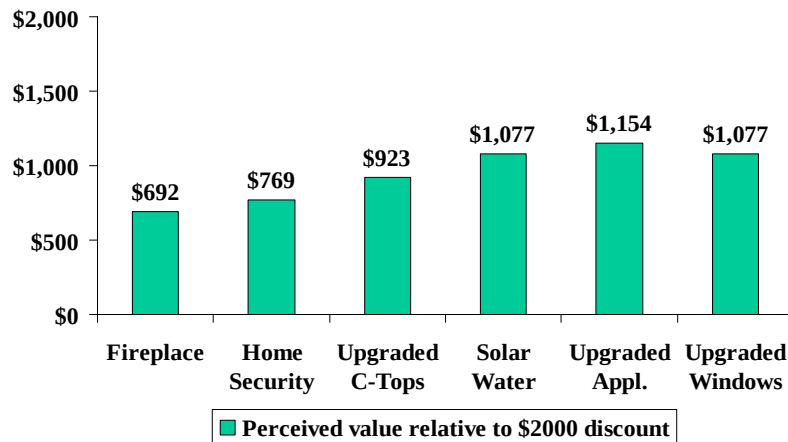
Perceived Value: Phoenix Low-End (\$100-150K)



Perceived Value: Phoenix Hi-End (\$150-200K)



Perceived Value: Las Vegas \$100-150K



Research Question #3

- ◆ What are the optimal solar water heater designs taking into consideration consumer preference and product feasibility?
- ◆ Method
 - Conjoint Analysis using a fractionalized design
 - 6 product features, each with 3 levels of variation
 - 729 possible combinations (profiles) represented by 27 randomly selected profiles
 - Respondents asked to sort and rank order 27 profiles according to their preference and likelihood of consideration

Product Features & Attributes

- ◆ Appearance
 - Basic blue/gray color with glossy finish
 - Custom color, coordinated with your house and a glossy finish
 - Custom color, coordinated with your house and a textured non-reflecting finish
- ◆ Capacity
 - Provides 40-50% of your hot water needs (one 4x8 panel)
 - Provides 70-80% of your hot water needs (two 4x8 panels)
 - Provides 90-100% of your hot water needs (three or more 4x8 panels)
- ◆ Brand -- *Backed by...*
 - Salt River Project
 - A well-known, national company
 - No known brand or company name



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Product Features & Attributes (Cont'd)

- ◆ Warranty
 - Standard 3 year warranty (no extra charge)
 - Extended 5 year warranty (\$100 - \$150 extra)
 - Premium 10 year warranty (\$200 - \$300 extra)
- ◆ Location
 - Installed on the roof of your house
 - Installed on the wall of your house
 - Installed on the ground in your yard
- ◆ Price
 - Installed price of \$1,000
 - Installed price of \$2,000
 - Installed price of \$3,000



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Conjoint Overview

- ◆ For the conjoint task, DMUs were first given an overview of solar water heaters. This overview consisted of a written description of the newer solar technologies which was read to them aloud by the interviewer. Following this written and verbal description, they were shown two 8x10 color photos of solar panels installed on people's homes. (These photos were provided to Symmetrics Marketing Corp. by NREL.)
- ◆ Following this introduction to solar, DMUs were given a stack of 27 individual cards that contained written profiles of solar water heaters. Each profile presented a different mix of product features and attributes. Individuals or couples were asked to perform the tasks outlined on the next page.

Conjoint Tasks

- ◆ DMUs (individuals or couples) completed the following tasks:
 - Review the 27 cards and sort them into one of three piles (Would Consider, Might or Might Not Consider, Would Not Consider).
 - For those in Would Consider and Would Not Consider piles, they further divided them into Definitely Would Consider, Probably Would Consider, Probably Would Not Consider or Definitely Would Not Consider.
 - Next, the DMU took the cards from each of the 5 piles (one pile at a time) and rank-ordered the cards from top to bottom (i.e., from the one they liked the *best* to the one they liked the *least* in that pile.) The end result was a rank-ordering of all 27 product profiles from 1 (like most) to 27 (like least).
 - Finally, the interviewer pulled out top 5 cards for each DMU and asked the DMU to rate each of the top 5 cards on a five-point purchase intent scale -- definitely would buy, probably would buy, might or might not, probably would not or definitely would not.

Conjoint Profile Example

- ◆ Shown below is an example of the conjoint profiles presented to study participants. The following profile was one of 27 profiles shown to participants on 4x6 cards.

Appearance:	Custom color coordinated with your house and a glossy finish
Capacity:	40-50% of hot water needs (one 4x8 panel)
Backed by:	A well-known, national company
Warranty:	Extended 5-year (\$100-\$150 extra)
Location:	Roof
Price:	\$3,000

Comment on Payback/Cost Savings

- ◆ In the design phase of this research the team wrestled with the idea of including monthly cost savings and projected payback period in the conjoint card sort task. Since cost savings and payback were a function of performance/capacity and installed price, we considered including projected cost savings and payback period as characteristics that would be estimated and included on each profile. (Technically, we would not “vary” savings and payback in the conjoint analysis since they would be derived from other features.)
- ◆ When we included savings and payback in the pretest, we found that many participants instantly focused on those numbers and ignored the other features entirely. Since savings and payback were not being directly varied in the conjoint analysis, we elected to omit them from the product profiles. Instead, we allowed participants to estimate cost savings and payback period for themselves if they were so inclined. In order to insure that participants understood the issues of cost savings and payback, we provided them with expected ranges during the general description of the new solar water heater systems.

Major Findings: Product Features

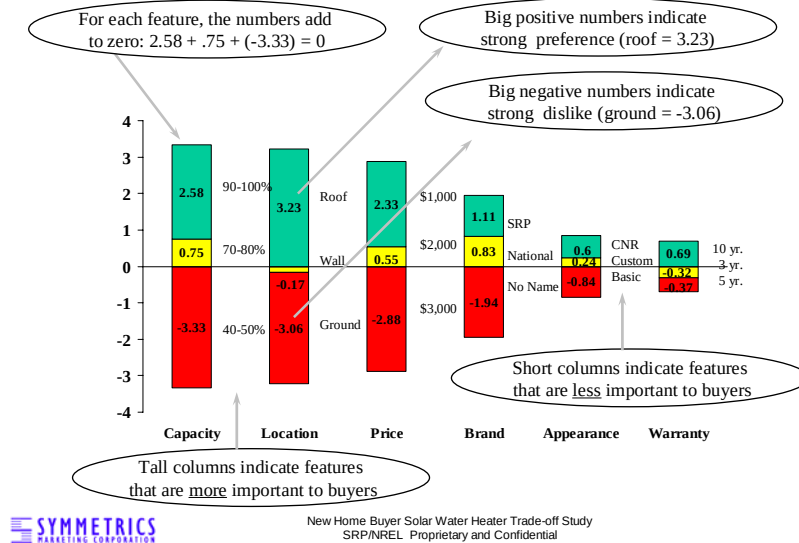
- ◆ Three major drivers of consumer preference
 - System capacity --consumers are concerned about the percent of their hot water needs provided by solar
 - Location -- consumers have very clear expectations about the location of the system (roof, wall or ground)
 - Price -- as expected, consumer preference is very driven by price
- ◆ Secondary driver
 - Brand association -- it clearly does matter to home buyers whether the solar system is backed by a credible, trust-worthy company
- ◆ Not a major issue
 - Appearance (as defined) or Warranty terms -- as long as the system meets the basic appearance criteria described consumers are satisfied. Similarly, of the system is backed by a credible source, the warranty terms become less important.

Worst Case vs. Ideal System

- ◆ Worst Case: Home buyers clearly not interested in a system that --
 - only provides 40-50% of their hot water needs
 - is located anywhere but on the roof
 - costs \$3000, and
 - is marketed by a company they've never heard of
- ◆ Ideal system would --
 - provide 90-100% of their hot water needs
 - be roof-mounted
 - cost ≈\$1000
 - be marketed by their local utility
- ◆ The value of conjoint analysis is the ability to determine the potential for success of product scenarios that fall somewhere between the *ideal* and the *worst case*.

Preference Drivers: How to Read Charts

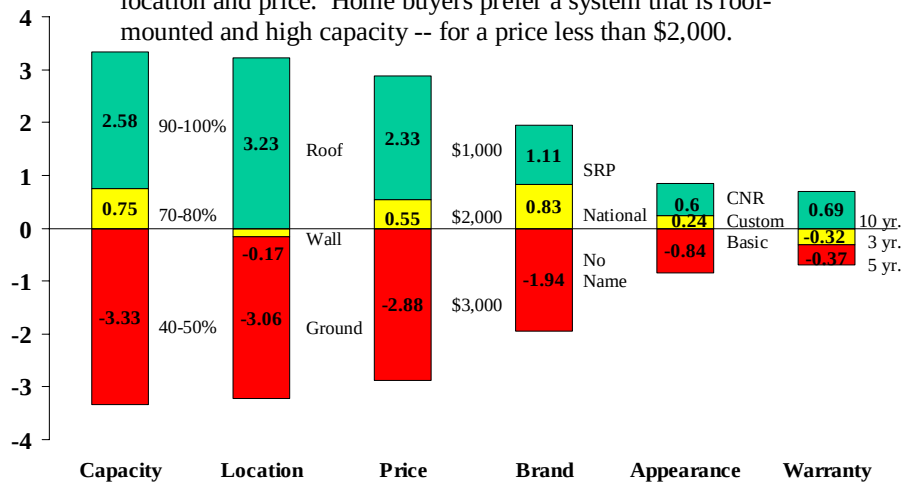
- The numbers on the following charts are statistics which indicate the relative preference for each of the design levels.



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Preference Drivers: Total Sample

- Overall, consumer preferences are strongly driven by capacity, location and price. Home buyers prefer a system that is roof-mounted and high capacity -- for a price less than \$2,000.



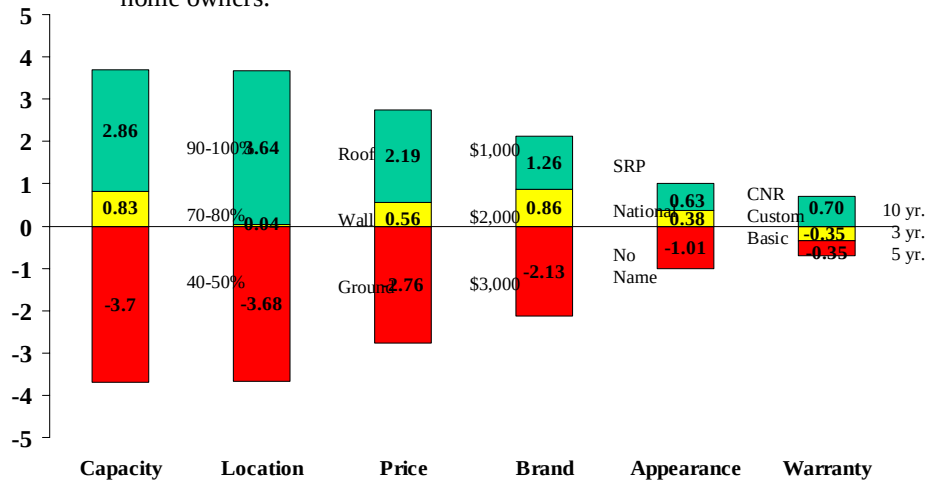
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Preference Drivers: Phoenix Low-End

♦ Capacity and location are the biggest issues for lower-end Phoenix home owners.

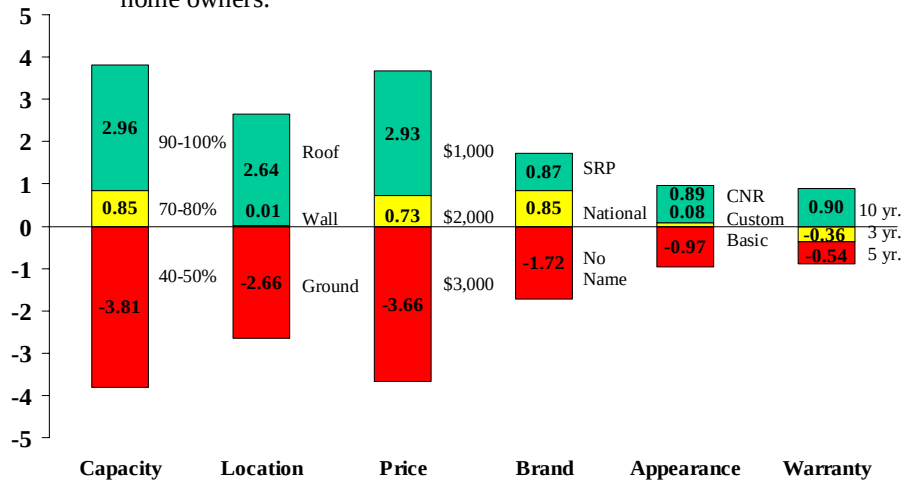


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Preference Drivers: Phoenix Hi-End

♦ Capacity and price are the biggest issues for higher-end Phoenix home owners.

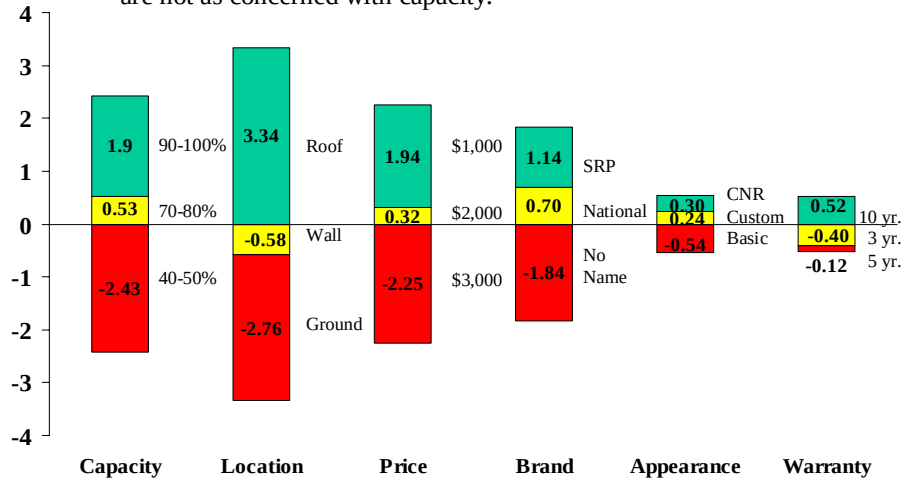


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Preference Drivers: Las Vegas

◆ Location is the biggest issue for home buyers in Las Vegas; yet they are not as concerned with capacity.

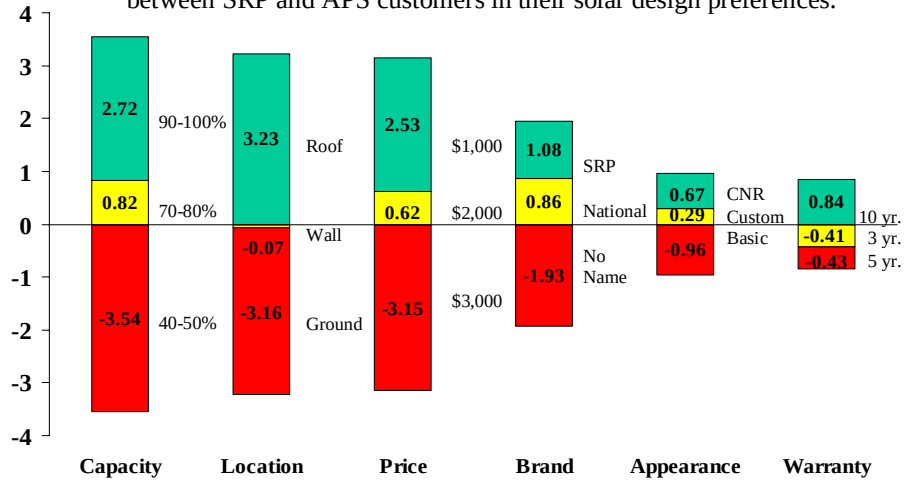


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Preference Drivers: SRP Customers

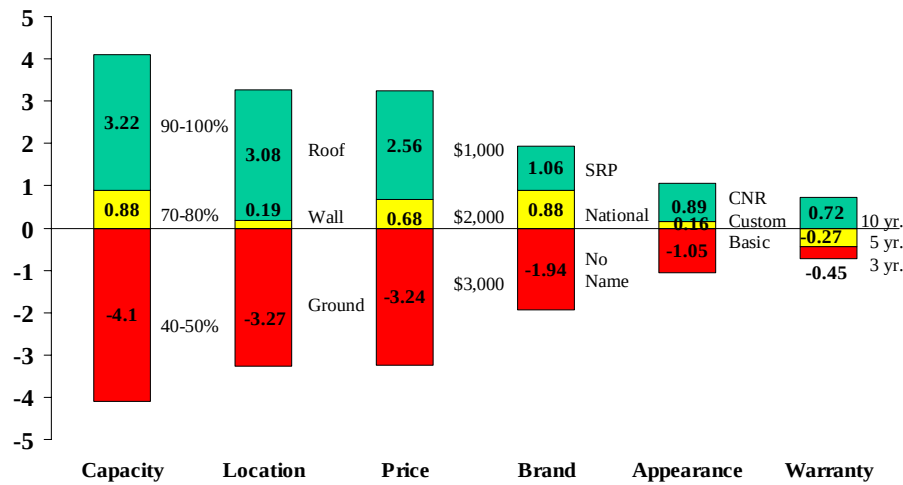
◆ As shown in the following two charts, there are no major differences between SRP and APS customers in their solar design preferences.



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Preference Drivers: APS Customers

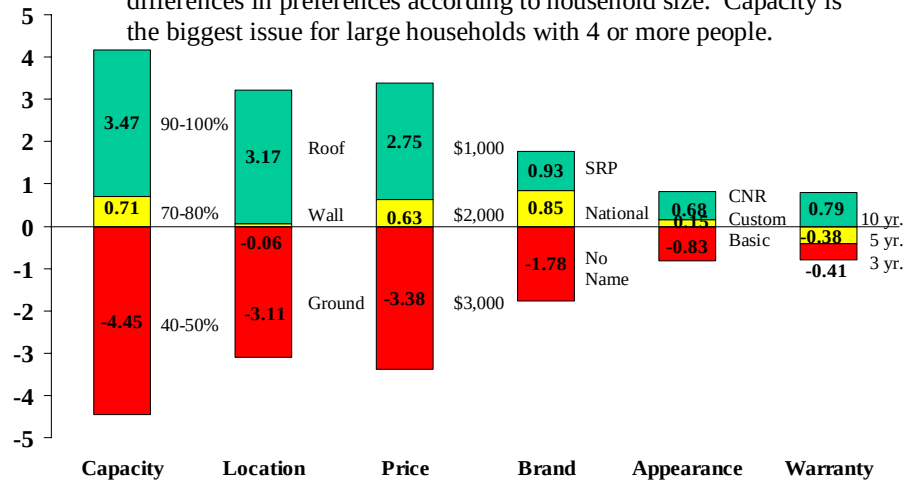


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Preference Drivers: Large Households 4+

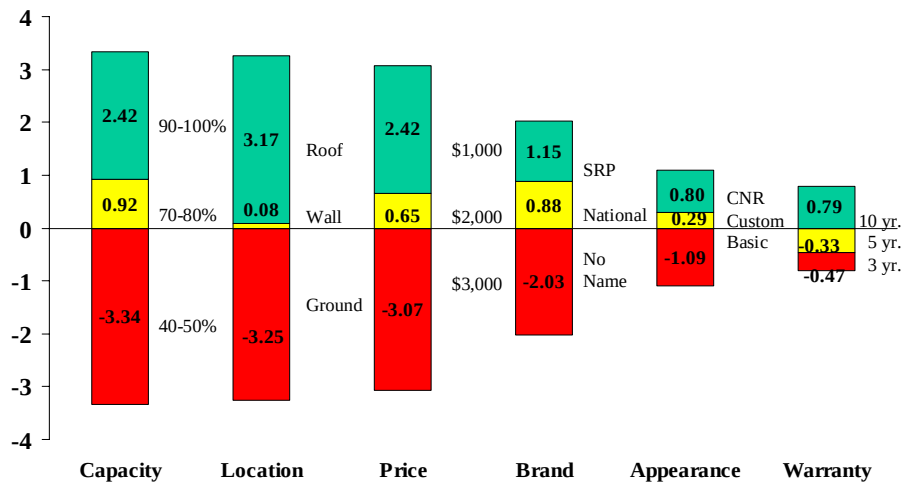
♦ As shown in the following two charts, there were some minor differences in preferences according to household size. Capacity is the biggest issue for large households with 4 or more people.



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Preference Driver: Smaller Households <4



Top Product Profiles

- ◆ The *ideal* system as discussed earlier would be one with “all the bells and whistles” for the lowest possible price. Conjoint analysis allows the researcher to examine preferences for all possible product profiles, not just the sub-set that was presented to the study participants. When all 729 possible profiles are rank-ordered, the Top 14 profiles all have the following features:
 - Roof mount, 90-100% capacity, \$1,000
- ◆ These “ideal” products may not be possible to produce or feasible to bring to market. As such, we need to look below this top tier to determine which profiles are appealing to consumers *and* feasible to manufacture/market.
- ◆ The table shown on the following page highlights the design features of the second tier of product profiles -- those rank-ordered from #15 through #25 (A complete rank-ordering from 1 to 729 has been made available to SRP/NREL.)

Profile Rankings: #15-25

- ◆ Purchase intention estimates (% definitely would buy) range from 20-30% for Profiles 15-25. Market potential may be considerably lower depending upon how the product is marketed relative to the other home options.

<u>Rank</u>	<u>Capacity</u>	<u>Location</u>	<u>Price</u>	<u>Brand</u>	<u>Appearance</u>	<u>Warranty</u>
#15	90-100%	Roof	\$2,000	SRP	Custom, non-reflect	10yr Warranty
#16	70-80%	Roof	\$1,000	SRP	Custom, non-reflect	10yr Warranty
#17	90-100%	Roof	\$2,000	National	Custom, non-reflect	10yr Warranty
#18	70-80%	Roof	\$1,000	National	Custom, non-reflect	10yr Warranty
#19	90-100%	Roof	\$2,000	SRP	Custom, glossy	10yr Warranty
#20	70-80%	Roof	\$1,000	SRP	Custom, glossy	10yr Warranty
#21	90-100%	Roof	\$2,000	National	Custom, glossy	10yr Warranty
#22	90-100%	Roof	\$1,000	SRP	Basic gray, glossy	3yr Warranty
#23	70-80%	Roof	\$1,000	National	Custom, glossy	10yr Warranty
#24	90-100%	Roof	\$1,000	SRP	Basic gray, glossy	5yr Warranty
#25	90-100%	Roof	\$1,000	National	Basic gray, glossy	3yr Warranty

Conclusions

- ◆ While solar water heaters suffer from a bad reputation, the new solar technology has potential with new home buyers.
- ◆ Interest in solar water heaters increased substantially once home buyers were “educated” about the new technology.
- ◆ The major perceived advantage to solar is lower energy costs -- solar marketers need to be able to demonstrate cost advantage and *payback* to home buyers.
- ◆ Home buyers currently have clear perceptions of the disadvantages of solar water heaters. Solar marketers need to eliminate perceived disadvantages -- *high initial cost, unattractive, unreliable, vulnerable to bad weather*

Conclusions (cont'd)

- ◆ In this study, solar water heaters were not as popular as upgraded energy-efficient windows or appliances *but* were more popular than upgraded countertops, home security or fireplace.
 - The top-3 (windows, appliances and solar) all have the potential to save money for the home buyer over time
 - Other features (upgraded countertops, home security, fireplace) may be viewed as less practical
- ◆ On average, home buyers would rather have a reduction in the price of their home (\$2,000 as tested in this study). Upgrade options may be viewed as luxury, not essential.

Conclusions (cont'd)

- ◆ The study was not able to identify any strong relationships between demographics and interest in solar water heaters. People were more likely to be interested in solar, however, if they had some prior experience with solar -- either in a previous home or through friends and neighbors. The following home buyer types were most likely to be interested in solar water heaters:
 - People in larger homes
 - People who have friends/relatives with solar
 - People who have previously owned a solar water heater
 - People who are more environmentally-conscious

Conclusions (cont'd)

- ◆ The biggest perceived *disadvantage* to solar is high initial cost. Home buyers will not consider solar water heaters if priced over \$2,000. Most expect the product to be in the \$1,000 to \$1,500 range.
- ◆ The three major drivers of consumer preference--
 - System capacity: *more is better* (at least 70-80% of needs)
 - Location: *prefer it on the roof*
 - Price: *\$1,000-\$1,500 range*
- ◆ Consumers also want the confidence of a local utility or nationally-known firm backing the product.
- ◆ Not as concerned with Color options or Warranty

Conclusions (cont'd)

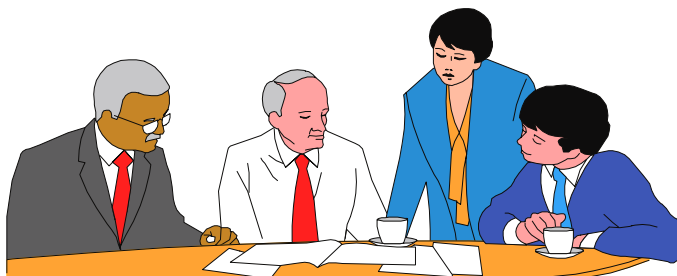
- ◆ Interest in solar water heaters was largely driven by *price* and *performance*
 - Consumers do not want to rely heavily on a backup water heater; they want nearly all of their hot water needs provided by solar -- *if this is not feasible, consumer education will be required to convince them of its value.*
 - Consumers do not want to spend \$2,000-\$3,000 for a water heater -- *for that kind of money, the payback is way too long*
- ◆ Solar marketers need to determine what type of unit can satisfy this price/performance trade-off

Final Comment

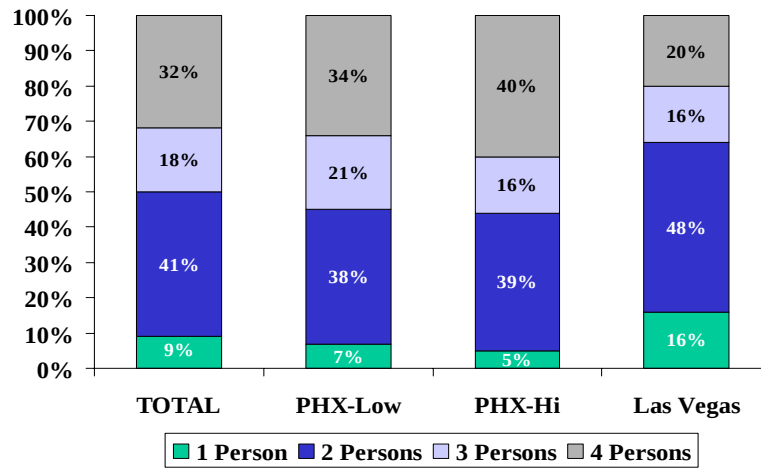
- ◆ The success of solar water heaters is dependent upon multiple players: *manufacturers, builders, realtors, consumers*. Consumer interest alone will not guarantee success.
- ◆ Solar marketers need to demonstrate to builders that there IS consumer interest in the product. This study strongly supports this view.
- ◆ Consumers will adopt solar if --
 - the cost/benefit is favorable to them
 - builders/realtors push the product

Demographics

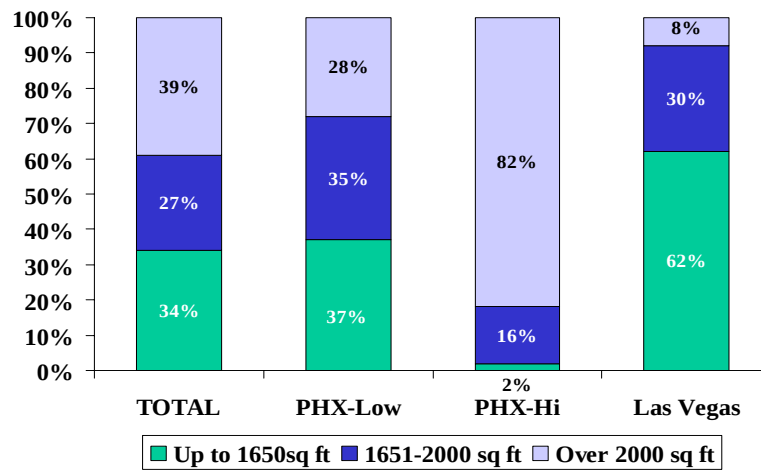
- ◆ Demographic Note:
 - The sample of home buyers recruited in Las Vegas tended to be older and of a lower socio-economic status than the sample recruited in Phoenix. This may have been due to several factors -- demographics of recent home buyers in Las Vegas, demographics near the focus group facilities, differences in recruitment lists. In spite of these differences, we did not see any major differences in solar preferences according to demographic variations.



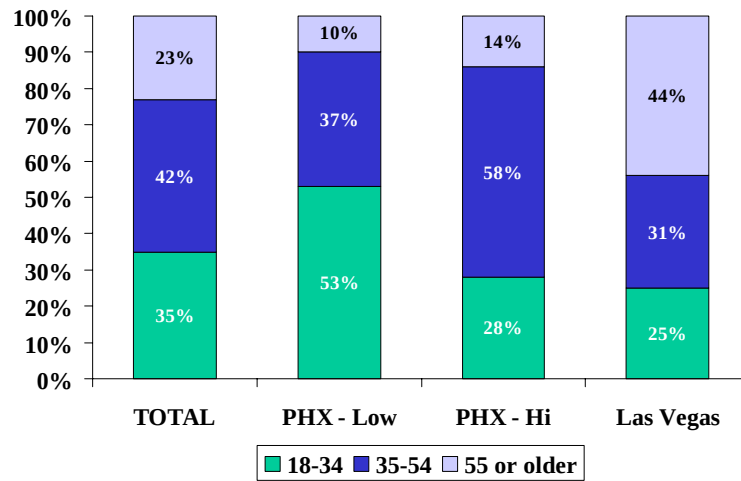
Household Composition



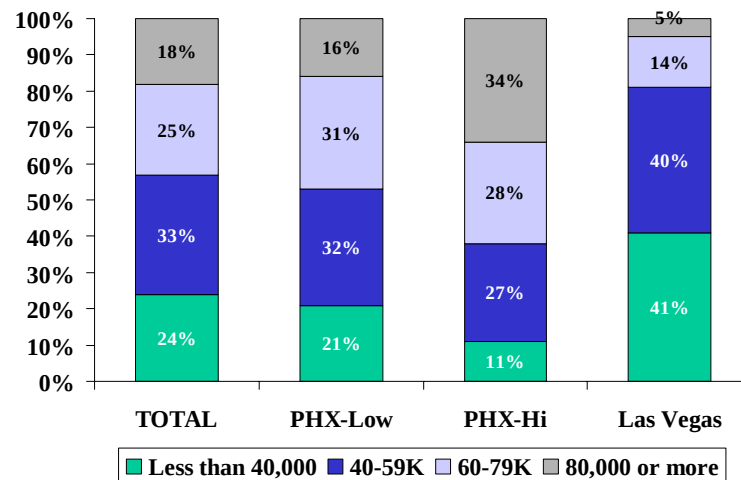
Home Size



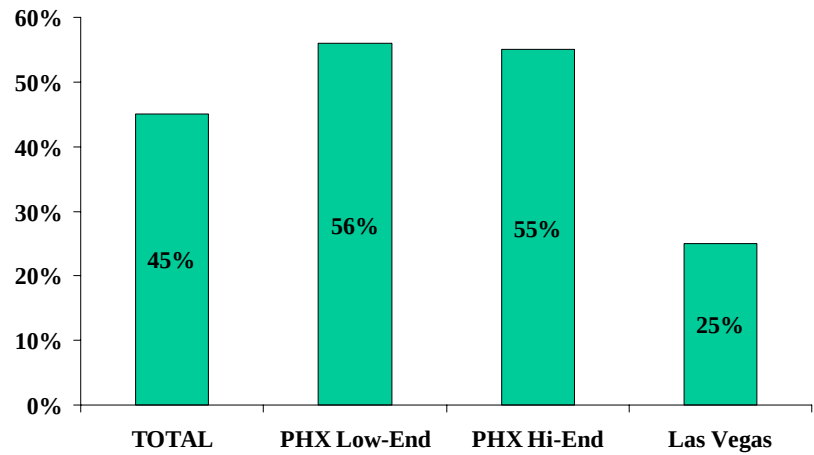
Age



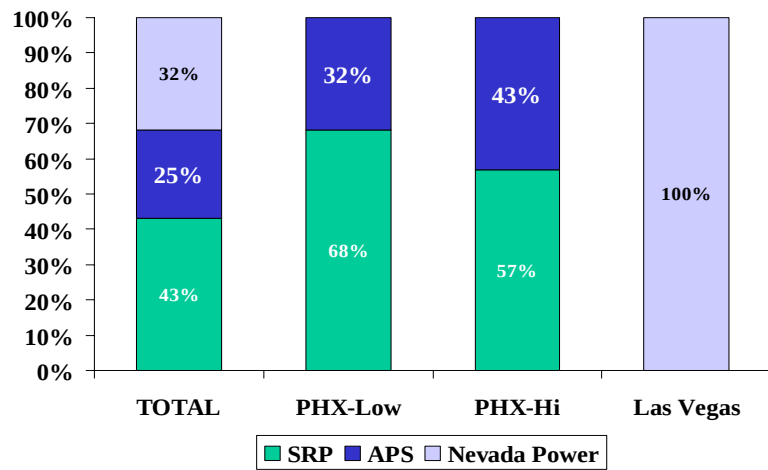
Income



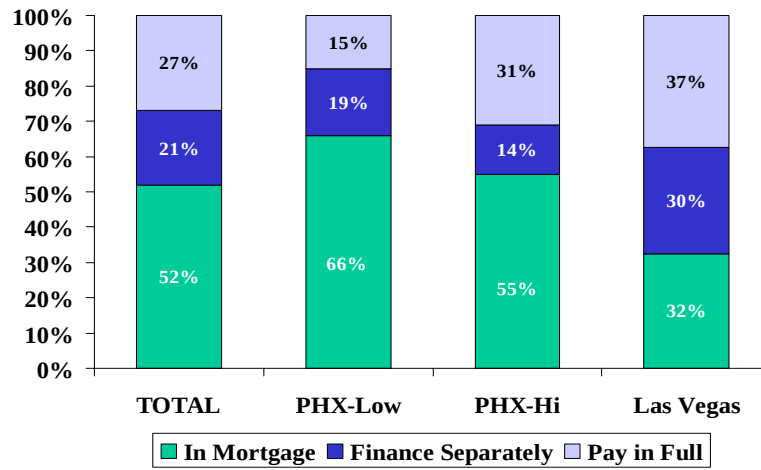
College Graduates



Power Provider



Solar Payment Preferences



**Appendix B.
Final Report of Solar Water Heating
Feasibility Study, Salt River Project (SRP) and
National Association of Home Builders (NAHB)
Research Center**



Solar Water Heating Feasibility Study

Roundtable Discussion

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June 21, 2006

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This report was prepared by the NAHB Research Center, Inc., under contract to the client. The primary authors of this report were Chris Fennell, Karen Johnson, and Christine Thompson Barbour.

Disclaimer

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EXECUTIVE SUMMARY

A daylong roundtable discussion was held with builders, homeowners association representatives, and trade contractors at the WestGroup Research Facility in Phoenix, Arizona, on September 15, 1998. The roundtable was conducted by the NAHB Research Center, Inc., under contract to the Salt River Project (SRP). SRP is developing a business plan and wants to determine the feasibility of integrating solar water heating into new homes. This report summarizes the barriers and establishes the solutions to the installation of solar water heaters in new homes from the perspective of key decision-makers.

Key decision-makers consisted of home builders, plumbing, electrical and roofing contractors, and homeowner association representatives. These respondents had positive reactions to energy efficiency saying that it meant saving money. They did not have negative reactions to solar water heaters, but thought that their current water heaters functioned adequately.

What are the solutions to integrating solar water heating into new homes?

In the morning session, builders, Homeowners Association (HOA) representatives, and contractors separated into groups according to their profession. They were presented with the specification sheets for the active and passive systems and told that a new community was being developed in which at least 50 of 100 homes would use the systems. Respondents identified the following barriers to implementing these systems:

1. Cost

Although respondents were provided with the cost of the system, they were worried about “hidden costs” that could result from additional labor, liability, and unforeseen problems.

2. Marketing

Respondents were concerned about being able to sell the idea of solar water heating to consumers because of its negative reputation. They want manufacturer support in advertising, training of installers, and product repair.

3. HOAs

Builders need to know what the requirements and covenants, conditions, and restrictions (CC&Rs) will be for communities in which they are building. Because CC&Rs are almost impossible to change once they have been developed, provisions for solar water heaters (SWHs) must be written into the CC&Rs when they are developed. Without the ability to enforce SWH usage legally, the CC&Rs are useless.

4. Aesthetics/Durability

HOA representatives were concerned about the appearance of the system. They suggested that the components of the system would not be able to endure the Arizona climate. After five or ten years, the panels may be faded and unattractive.

5. Liability

Respondents were concerned that they would be held liable for the system if it fails. They wanted to be assured that they could count on the manufacturer if held liable for the system.

6. Location

Contractors need precise locations for where the system can be installed, depending on the orientation of the home. The contractors stated that homes on some lots would be unable to use the system because of their orientation.

What are the solutions to integrating solar water heating into new homes?

In the afternoon session, respondents were divided into heterogeneous groups to discuss solutions to the barriers they had identified in the earlier sessions.

Cost: There are many opportunities to reduce SWH costs by eliminating hidden costs such as multiple markups through the distribution chain and reducing trade contractor labor in the field. Manufacturer and government incentive programs can increase sales volumes and introduce economies of scale.

Marketing: To establish consumer acceptance and demand, the solar water heater manufacturer must target sophisticated move-up homebuyers with print, radio, and point-of-sale advertisements and sales support materials.

HOAs: Input should be sought from property management companies and developers early in the process, often 18 months before construction begins, to develop CC&Rs that can be enforced by HOAs.

Manufacturer Cooperation: Production builders expect comprehensive manufacturer support programs that extend from installer training and in-field technical support before the sale to maintenance and warranty programs for homeowners. Warranties should be underwritten by an independent insurance company.

Location on Home: The builder should provide the installer with approved locations for solar collector placement on the home that are indicated on small cut sheets with elevation drawings. The cut sheets should indicate precise distances that the unit should be from a clear reference point such as a ridge line.

Site Orientation: Due to site constraints, some homes should not be offered with solar. Builders fear that their customers will find the SWHs ineffective and share this information with their neighbors and friends.

CC&Rs: Language must be included in CC&Rs that states the appearance, maintenance requirements, size, system type, color, etc. that will be acceptable in the community.

Aesthetics/Durability: The solar collector must look and be installed much like a skylight utilizing a curb and cricket technique. It should be installed in the same plane as the roof and have an integral flashing that accommodates conventional weatherization techniques. The solar equipment manufacturer should supply all of the needed components and use universally available parts and fasteners to facilitate repair and maintenance.

Trained Contractor Availability: There was consensus that plumbers should install the solar water-heating systems. The manufacturer would need to provide technical training. Third-party installer certification program would increase builder confidence and increase installer competence.

INTRODUCTION

Background

The Salt River Project (SRP) is one of Arizona's largest electric utilities and water providers with over 650,000 customers. It is evaluating the manufacture, sale, and installation of solar water heaters (SWHs) as a new business opportunity. A key market for SRP's solar water heater initiative is new residential construction.

The NAHB Research Center conducted a series of focus groups with builders, architects, and trade contractors in Arizona, California, and Florida during 1997 on behalf of the National Renewable Energy Laboratory and SEIA. The results of that study indicated that aesthetics, trade contractor integration, consumer demand, and cost were the most significant hurdles to the widespread use of solar water heating in new homes. The market feedback also indicated that currently available SWHs do not meet their needs or the needs of their customers.

Purpose

The purpose of this research is to identify barriers and establish solutions to the installation of SWHs in new home construction through synergistic communication with key and influential decision-makers. The results of this study will be used as an input to SRP's development of a solar water heating business plan.

Method and Scope

A daylong roundtable discussion was held with builders, homeowners association (HOA) representatives, and trade contractors at the WestGroup Research Facility in Phoenix, Arizona, on September 15, 1998. The roundtable discussion was held with builders, HOA representatives, and trade contractors. Initially, all respondents met together and discussed their perceptions of energy efficiency in building and energy efficiency as it relates to water heating. Specifications for active and passive solar water-heating systems were introduced to the respondents, who were then divided into homogeneous groups to identify issues and concerns with the systems. The groups then reconvened in a plenary session to present their findings. The respondents were then divided into two heterogeneous groups to discuss solutions to the barriers outlined in the earlier sessions.

The agenda was as follows:

8:30 - 9:15 a.m.	9:20 - 10:30 a.m.	10:45 – Noon	1:00 – 2:15 p.m.	2:15 – 4:00 p.m.
	WHAT ARE THE BARRIERS?		WHAT ARE THE SOLUTIONS?	
Introduction	Homogenous Discussion Groups	Plenary Session	Heterogeneous Discussion Groups	Plenary Session
Participant greetings. Focus discussion on <u>process</u> issues rather than product issues. Provide product design parameters, specifications, how SWHs work, etc. Facilitated by Chris Fennell and Christine Barbour, NAHB Research Center.	Respondents broke into three groups to discuss their issues and concerns related to solar water heating. They were facilitated as follows: Builders – Christine Barbour Trade Contractors – Chris Fennell HOA Representatives – Colleen Warner, SRP	Respondents converged to outline their issues to the group. The discussion was moderated by Chris Fennell and Christine Barbour.	Respondents were broken into two groups, each consisting of builders, contractors and HOAs. Group A was moderated by Christine Barbour and Group B was moderated by Chris Fennell.	Each of the groups presented its findings. This was followed by a moderated discussion, which was facilitated by Christine Barbour and Chris Fennell. After the discussion, client representatives from SRP were introduced to the group.

The respondent characteristics are as follows:

BUILDERS						
Respondent	1	2	3	4	5	
Company	Beazer Homes	Pulte Homes	Richmond American Homes	Shea Homes	U.S. Homes	
No. homes	1,500	800–900	1,000	1,800	500–600	
Price range	\$80,000–250,000	\$150,000–400,000	\$120,000–220,000	\$70,000–500,000	\$150,000–200,000	
HOMEOWNERS ASSOCIATION REPRESENTATIVES						
Respondent	1	2	3	4		
Title	Manager	Manager	Manager	General Manager		
Community Type	634-home community	Several HOAs	241-home community	Several HOAs, from 50 to 1,000s of units		
TRADE CONTRACTORS						
Respondent	1	2	3	4	5	6
Type	Plumber	Roofer	Roofer	Plumber	Plumber	Roofer
Years experience	20	30	7	-	25	13

Statement of Limitations

Qualitative market research seeks to develop insight into attitudes, beliefs, and opinions rather than quantitatively precise measures. Because of the limited number of respondents and the restrictions imposed upon recruiting, this research must be considered in a qualitative frame of reference.

The reader is reminded that this report is intended to clarify ambiguous issues and indicate the direction for future research. The data presented here cannot be projected to a universe of similar respondents.

The value of qualitative market research is in its ability to provide unfiltered, unbiased comments from a segment of the target population and for decision-makers to gain insight on the perceptions of their consumer base.

PART I: WHAT ARE THE BARRIERS TO THE INTEGRATION OF SOLAR WATER HEATING INTO NEW HOMES?

General Energy Efficiency

All respondents initially met together in one mass meeting to discuss their perceptions of energy efficiency, both in general and in its relation to water heating.

Energy Efficiency

Generally, respondents associated energy efficiency with either saving money or making trade-offs between cost-effectiveness and energy efficiency. Respondents associated energy-efficient products with saving money and decreasing waste. They identified certain products, such as dual-pane windows, higher-efficiency appliances, and insulation, with energy efficiency, and also noted that the design and layout affected a home's efficiency. They felt that energy efficiency would become more pervasive in the future as a result of codes. They suggested that more advanced materials and systems would become available that would decrease construction cycle time and address labor shortages. They also predicted that homes would be designed for energy efficiency. They stated that consumers would continue to become more educated about energy efficiency and environmental friendliness, but they would be savvy about their purchases as investments that need to demonstrate a return on money.

REACTIONS TO ENERGY EFFICIENCY

When You Hear the Term
"Energy Efficiency," What
Comes to Mind?

- "Saving money."
- "How long it will take before I benefit from the money we're going to save. There's a time limit."
- "Cost versus efficiency. How much you're going to pay to get that efficiency. It comes back to the return."
- "Consumer perception. What they define as energy efficient."
- "Different types of products. Dual-pane windows. SEER ratings."

What Makes a Home Energy
Efficient?

- "Minimal waste."
- "Insulation."
- "Higher SEER ratings on the air conditioning."
- "Design, layout."

What Trends Do You Envision
for Energy Efficiency?

- "We're going to have more advanced materials."
- "More efficient use of manpower, resources."
- "Changes in codes. Whether they're going to upgrade to be more efficient."
- "More efficient building procedures. It's going to

be zeroed in by the codes because it's going to make it that much harder to meet, so you're going to have to advance to keep up."

- *"Design changes."*

Are Consumers Going To Be Thinking More About Energy Efficiency?

- *"The average consumer is a lot more educated about products than they were 20 years ago, 10 years ago. They're probably only going to get more educated."*
- *"They'll want more return on their money. They'll want to know what it's going to cost and how long it's going to take to recoup that investment."*

Energy Efficiency and Water Heating

Respondents were asked about the role of water heating in energy efficiency. Most initial responses were neutral. They felt that current methods of water heating (i.e., gas and electric) were already inexpensive and did not contribute to high-energy usage like other appliances, particularly air conditioning. They further suggested that consumers were not interested in their water heating systems. They want a system that works, they do not have to think about, and that will save them money. Gas was the preferred utility. Although they perceived gas as more expensive initially because of the first cost and costs associated with trenching and putting in a line, they felt that gas is more efficient and less expensive than electric in the long term. Nonetheless, some consumers dislike gas because they perceive it as unsafe.

Respondents noted that builders can receive credit in the form of a rebate from Southwest Gas. The credits are based on each fixture that has a gas hookup and the number of units in a community. They also received credits for doing their own trenching. Southwest Gas began offering these credits in response to the construction boom and the rebates that were offered by SRP and APS. They noted, however, that the credits offered by SRP and APS *"are close to gone away"* or *"gone away all together."*

Respondents immediately began discussing solar water heating when they heard the terms "energy efficiency" and "water heating." They discussed their concerns with solar water heating, stating that most consumers, who are primarily interested in price, would not be attracted to solar water heating because of its low initial payoff and its unreliable reputation. They also noted that aesthetics are a concern with solar collectors. Builders stated that covenants, conditions, and restrictions (CC&Rs) in new communities do not allow components on the roof. Despite these concerns, they stated that the Arizona climate is ideal for solar water heating, and some respondents noted using solar water heating themselves. Most respondents were familiar with applications for heating pools and hot tubs.

What Role Does Water Heating Play in Energy Efficiency?

- *"The bottom line for most people—they want a good product...right now, there isn't one product that is so much better than anybody else's in terms of residential water heating. People want to know what*

it's costing them. For most people, that's the bottom line. Am I saving money?"

- *"I think when the consumers are in there buying their home, water heating really doesn't come into play that much."*
- *"When they first buy a home, they don't look at the water heater at all."*
- *"It's probably fifth or sixth or seventh on his list."*
- *"When you're looking at \$25-\$35 a month maximum [for gas or electric water heating], it's a low-priority item."*

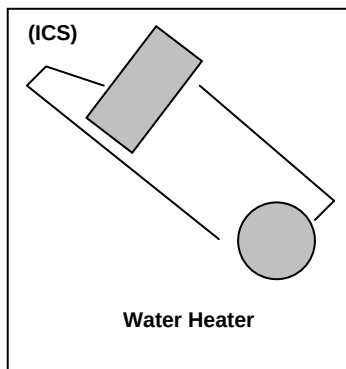
What Are Your Reactions to
Solar Water Heating?

- *"I have solar water heating for both my domestic hot water and my spa."*
- *"[Consumers] are asking about other alternatives, about solar heating."*
- *"Right now, I think a lot of people have a bad taste in their mouths for solar...because the systems weren't put in properly."*
- *"Another big concern would be aesthetics...I have the flat roof tile...I think it looks gorgeous. I wouldn't want to see solar panels."*
- *"Most of our CC&Rs in our new communities will not allow you to put things on the roof. So that is a big concern."*
- *"A few years ago, solar heating was the big thing here in the valley. The problem we ran into though was everyone got on the bandwagon and everyone started putting in solar water heating, even though they weren't qualified to do so."*

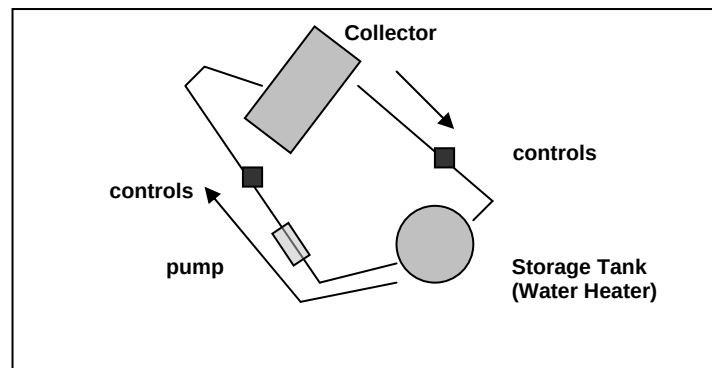
Breakout Discussion: Homogenous Groups

Builders, HOA representatives, and trade contractors were separated into different rooms. They were presented with the specification sheets for active and passive systems and told that a new community was being developed in which at least 50 of the 100 homes would use the systems. They were asked to discuss, from their respective viewpoints, what issues and problems they would need to solve in order to implement the solar systems into the new community.

Passive Solar Design



Active Solar Design



Problems/Issues

When respondents were presented with the solar system, they automatically accepted their role as promoters of the solar system. They were initially more concerned about how to convince others to use the system than about being convinced themselves. They felt that education would have to be a priority for them—they would need to educate buyers, sales people, and municipalities on how the solar system operates and why it is advantageous.

Cost. Builders were especially concerned with the cost of the system. They feared “hidden costs” associated with the system, such as raised fees from trade contractors, permit fees, inspections, and the paperwork associated with installing an optional water heating system over the standard system. They were also concerned about whether the systems will remain cost-competitive and whether the payback time is short enough to interest consumers.

Liability and Warranties. Both builders and contractors were concerned about their liability and the additional warranties necessary for a solar system. Because adding penetrations to the roof increases the chance of leaks, respondents wanted to be assured that they would have the support of the manufacturer. An extended warranty that is equal to or better than conventional water heater warranties is needed because it is a new product. Contractors wanted the builder to be enthusiastic about the product, and they wanted to know that the manufacturer behind the product was reliable. HOA representatives were clear that they would not be responsible for a solar system. They stated that it would be the responsibility of the homeowner unless it was installed on a multifamily unit.

Installation. Builders were particularly stressed that the systems should be easy to install because they were concerned about an increase in manpower. They agreed that plumbers should install the system, and that it should be installed like a skylight, after the dry-in stage and before the tile stage. They acknowledged that roofers would also be necessary for any work on the roof. An additional concern for builders was whether 50 of the homes in a community could be oriented with the southern exposures necessary for solar power.

In order to install the system, contractors stated that they would need to know:

- The wet weight of the panels
- The number of panels as related to the size of the home and the amount of hot water needed by the home
- How the piping will be insulated
- The exact location. Contractors expect the builder to specify where on the home the solar panels should be placed.
 - Four approved locations should be shown on the builder's blueprints to accommodate for different orientations on the house. They should also be documented on separate spec sheets.
 - The top of the solar panels should be 24 inches from the top of the roofline so the tile lines up properly and do not need to be cut.
 - The builder must identify certain lots that cannot get solar due to their orientation.
- How the home will be designed to maximize the efficiency
- Specifications on how the system should be connected
- The size of the panels, the pump, and the storage tank
- Specific measurements
- Installers would want the installation instructions to include:
 - Shutoff valve requirements and locations
 - Wet and dry weight
 - Flow calculations
 - Minimum number and size of panels for a given home size or occupancy
 - Gallons or energy delivered

Maintenance and Repair. Both builders and contractors expressed concern that the system would not be easy to maintain and repair because it would be difficult to access. They felt that homeowners would not maintain their systems.

"Most people are not mechanically gifted enough to really drain a water heater."

Aesthetics. HOA representatives stated that they would be concerned primarily with the aesthetics of the system. They did not think that the systems shown in the pictures were objectionable, but they wanted to be sure that they would still be attractive after five or ten years. They were particularly concerned that the Arizona climate would fade or damage the panels after years of exposure.

CC&R Limitations. Most builders did not perceive CC&Rs as a problem when implementing solar water heating into new homes because the builder can help create the CC&Rs when developing the community. However, once CC&Rs are established, they are almost impossible to change. The HOA representatives made clear that they are not responsible for developing CC&Rs—builders and developers are responsible for developing CC&Rs for the community before it is built. A particular concern for HOA representatives is that the CC&Rs are written in a way that allows them to be enforced. Enforcement may include taking homeowners to court to compel them to abide by the CC&Rs.

“It’s real tough when you’ve already got them established. These become public documents that are attached to the project. In the beginning, you would have a lot more feedback. Basically, it goes back to marketing. The idea of CC&R is to market a community that has protections and certain things that appeal to the buyers. Again, you have a latitude in the beginning stages when you put those together. There are canned packages, but you can still make adjustments and changes to it.”

Marketing. All groups stated that the systems would be difficult to market because of solar water heating’s dubious history. However, HOA representatives felt that solar water heating systems might increase the value of the homes in their communities because *“you have another energy-efficient component that your community can sell in a resale market.”*

Active and Passive Systems

Respondents were asked to discuss the active and passive solar water heating systems, and to decide which they would recommend for the community. Neither builders nor HOA representatives stated that they preferred one system over another based on the information they had available. Builders wanted to know the weight and maintenance associated with the system, and questioned why the passive was not less expensive than the active system. HOA representatives, who were mostly concerned with aesthetics, wanted to know how the systems would look after five or ten years of exposure. They did not prefer the appearance of one system over another, but stated that they thought the passive system would be easier to maintain than the active system.

Trade contractors immediately stated that they would prefer the active system. They felt that the passive system might not work well in the morning because heat loss occurring overnight would limit hot water supply, and because the additional weight on the roof would require additional support. They also felt that all of the panels should be the same size and type so neighbors would not compare systems.

WHAT ARE YOUR CONCERNS WITH INTEGRATING SOLAR WATER HEATING INTO NEW HOMES?		
BUILDERS	TRADE CONTRACTORS	HOA REPS
“We have to figure out a way to educate the homebuyer. Educating the salespeople would probably be the first step in educating the homebuyer.” “You have to educate the construction staff, your own people...also the actual trades. The construction guys are indirectly are also involved in homebuyers in marketing. They have to know how to explain the product to the homeowners.” “Are we alone in this or do we have competitors in the immediate area required to do this? Sometimes you can turn this into a marketing advantage.” “I think we need to find some way to understand the value equations as far as function versus cost...it may be necessary to have them on 100% of the home. It’s in the design of the product instead of having it as an option. Instead of being required to do it by CC&R, we want to do it. We just have to understand what it’s going to cost.” ““Are there additional permit fees in selling this?”	“My first reaction is, is this a warm fuzzy? Are you [the builder] excited about this? Is it okay with you?” “My concern would be choosing your manufacturer. A lot of people don’t have business making tanks and panels.” “My main concern is going to be re-educating the public.” “I had two thoughts. First, how is the water pipe going through the roof deck. The second is, how much money is it going to cost me when the idiots that work for me break the glass in the collectors?” “Access to panels on the roof.” “One of the things is I need proper installation. From what I’ve looked at and seen, anything that is over 4 feet wide has to have a cricket... You have to be able to make that water go around.” “If the thing is put in right, you should never have to get on the roof to see the panel.”	“What’s the cost and does it work?” “How is it going to pay for itself?” “How soon is the homeowner going to have to pay for repairs on this unit? Is it going to leak from the roof?” “Aesthetics are a big issue...Now there is some new, skinny stuff up. It’s still a big, black thing sitting on your roof... [CC&Rs are] looking at aesthetics more than they’re looking at anything else.” “This looks to be single family dwellings, so it’s not going to affect the association costs. It’s not going to affect the association as far as maintenance and upkeep. That’s the homeowners responsibility. The way that this is presented to us, it’s just aesthetics.” “I think everyone envisions what was put in the ’70s and early ’80s...I’m basing all of this on past perceptions.” “I think you’re going to have to prove that the new unit will work, cost less and look attractive on a roof to the homeowner before they are even going to consider it.”

WHAT ARE YOUR CONCERNS WITH INTEGRATING SOLAR WATER HEATING INTO NEW HOMES?		
BUILDERS	TRADE CONTRACTORS	HOA REPS
<i>“I’m wondering how you get it up [on the roof].”</i> <i>“There is that little niche out there, but it’s a very small niche [for energy efficiency]. Unless you can do these things and keep the costs so they’re competitive with what the other builders are doing.”</i> <i>“The concern is qualified contractors to perform additional work.”</i>	<i>“The houses we re-roof that have solar on them, I would say 80% the solar is non-functional when we get there.”</i> <i>“Are we saying that all roofs are going to be tile?”</i> <i>“Is it an anti-freeze system or is it directly heating the water?”</i>	<i>“Who is going to maintain it? Who is going to fix the roof?”</i> <i>“Whose insurance does it fall [under]?”</i>

AFTER EXAMINING THE SPECIFICATIONS FOR THE ACTIVE AND PASSIVE WATER HEATING SYSTEMS, WHAT COMMENTS DO YOU HAVE?		
BUILDERS	TRADE CONTRACTORS	HOA REPRESENTATIVES
<i>“In looking at the information, I would assume that there is value in having an active system. If there is, why would anyone buy a passive for \$2,000?”</i> <i>“This product is more than \$2,000 from the get-go. Not knowing if there is permit fees, you know your roofers are going to charge you more because it’s another penetration to the roof.”</i> <i>“I’m going to throw out some numbers, and I’m not saying I’d go out and buy anything for these prices. I think your passive around \$800 and your active</i>	<i>“My opinion is the passive system is not going to yield [as much] because all day it’s heated the water up nice and then it gets piped into the water heater before it gets brought into the house. As it sits overnight and radiates the heat that it’s collected back out again, if first thing in the morning you have no hot water, there is no savings.... With an active system, you’re storing very, very little water on the roof, so you’re not losing much out of the system. At night the water is sitting in the storage tank.”</i> <i>“The only loss with an active system is probably water in the panel, but as long as</i>	<i>“Looking at this as new construction, I don’t think there is really any differentiation between the two when you’re looking at it. The only thing the association looks at is the aesthetics and the long-term maintenance of it and the way it’s constructed...Whether it’s an active or passive system, which is better, which isn’t, I don’t think the association cares one way or the other.”</i> <i>“Just the way it looked aesthetically, I don’t think the association would even come to attention. It becomes attention when it comes back to the retrofits and</i>

AFTER EXAMINING THE SPECIFICATIONS FOR THE ACTIVE AND PASSIVE WATER HEATING SYSTEMS, WHAT COMMENTS DO YOU HAVE?		
BUILDERS	TRADE CONTRACTORS	HOA REPRESENTATIVES
around \$1,200. I would think you've crossed yourself out of the market for anything above that. I don't care what kind of marketing you have, that's too much to work with." "We have limited information here." "It seems like the active is going to cost more to operate and more to go wrong." "If you're required to have 50% of the homes having this unit, you need to somehow guarantee that those lots can accommodate a southern exposure."	freeze protection comes on and circulates some water from your surge tank through the solar protector to keep it from freezing. You may have to have additional roof framing to support the extra weight of the passive system." "It depends on the price conscience of the contractor. Sometimes the homebuilder is going to dictate by price what system is going to go on." "I wouldn't [recommend] a mix [of both systems] within the community because you have people comparing. I'd almost be afraid of having different sizes."	you're putting stuff up there, debris gets caught underneath it. Or blocks the view of the neighbor." "We'll see what it looks like in 5 or 10 years." "We would have to look into where the pumps are at and how the association would get to them and that type of thing." "If you're looking at something that you have to maintain, the less moving parts and the less things to break down, that's what the association board is looking for, or management company." "The efficiency difference would have to be large to prefer active over passive."

Installation

Trade contractors were asked to detail the installation process of the systems. They suggested the following:

- (1) The framer builds a curb using a 2 × 6. A curb height of 3 to 5 inches is needed to allow for a cricket for panels wider than two feet to divert water and accommodate the height of the tiles.
- (2) The roofer installs curb flashing—the collector should come with integral counter flashing.
- (3) The plumber installs the piping and stubs it out for the connections to the collector during “top out” (the second phase of plumbing) at the same time that the water supply and drain-waste-vent piping is installed for the rest of the home.
- (4) The plumber installs the panel during “trim” (the third phase of plumbing) at the same time that fixtures, faucets, etc., are installed. The penetrations are below it, not through the curb. The stub out could be connected to nipples on the bottom of the panel using flexible hot water pipes. Lag bolt through integral brackets into the curb from the outside. The glass should be easy to remove and less breakable.
- (5) The plumber installs the tank, pump, and controller during “trim” (the third phase of plumbing).
- (6) The roofer installs the tile or shingles.

“If it came with the flashing in the roof and the plumber was responsible, to me that’s an essential part of my roof.”

PART II – WHAT ARE THE SOLUTIONS TO INTEGRATING SOLAR WATER HEATING INTO NEW HOMES?

Purpose

The purpose of the afternoon session was to eliminate barriers to the adoption of solar water heating that were identified in the morning sessions.

Method

Respondents broke into two groups composed of builders, contractors, and HOA representatives. As groups, they resolved any issues from the morning session to develop a process for integrating solar water heating into homes that met all of their individual needs. They presented their findings to the group as a whole. At the end of the session, SRP was introduced as the client for this project. This section of the report presents the issues from the respondents' perspectives and the solutions, which they developed.

Issues and Solutions to Incorporating Solar Water Heating into New Homes

ISSUE: Homeowners do not ask for solar water heating. Builders do not perceive solar water heating to be an option from which they can profit; therefore, they do not offer it on their homes.

SOLUTION: To be attractive to builders, SRP must create a consumer demand for solar water heating through education. If consumers ask for solar water heating, builders will provide it, if it is financially attractive to them. If it does not meet their first cost, installation cost, and profit criteria, there must be rebates. Homeowners need to be able to forget that they have solar water heating until they see the results of a positive monthly cash flow.

“It’s another product that as a builder we would be willing to put in, if we felt that there was a demand for it.”

“So you can prove the demand and do something to defray the cost, and then provide the necessary support, albeit financial, marketing, training, all of these things.”

“From a builder’s standpoint, the first thing you’d need to do is prove that there is a demand. Because that would be something that I’m still a little concerned on.”

“I think you have to back up a step from that and maybe even create the demand in the consumer base, rather than just prove that there is a demand.”

ISSUE: Solar water heaters are too expensive. They will cost more than \$2,000 because of the hidden costs involved in their installation.

SOLUTION: To resolve this issue, each group was given the assumption that the SWH unit would perform according to specifications, and meet consumer demand. Respondents then took the \$2,000 target and backed the hidden costs out of this. The table below shows a composite of the information of both groups. All comments should be considered from the production building perspective. The cost estimates are based on input from an extremely limited sample and may not be representative of the Phoenix area building community as a whole. The following solution satisfied their concerns to a great extent.

WHAT ARE THE HIDDEN COSTS OF A SOLAR WATER HEATING SYSTEM?		
	Unit cost	Assumptions
Cost to manufacture	\$820	Working backwards from \$2,000 this would be the cost of the manufactured product to the distributor. The price would include overhead; direct labor; material including controls, pump, sensors, tank; sales; equipment; marketing; and warranty.
Distributor markup	\$120	Assume two-step distribution with 15% to 20% distributor markup.
Plumber labor	\$360	Additional cost to the builder: \$35-60/hour to run pipes (1 laborer for 2 hours); install panel on the roof (2 laborers for 2 hours).
Plumber materials	\$100	Assume 40-foot additional piping run with 30% to 35% margin on materials.
Framer labor	\$75	Additional cost to the builder for platform/curb/trusses/cricket with lumber scraps.
Larger water heater tank	\$200	Additional cost to the builder to upgrade from 50 to 120 gallons.
Electrician labor	\$35	Additional cost to the builder to tie in the pump with 220 volts and a 35% margin.
Roofer	\$140	Labor and materials for flashing (15 minutes) \$40 (typical cost for a skylight is \$25 – \$45) and cricket.
Architect	\$100	One time and recurring design changes. No dollar amount given – assume 2 hours at \$50 per hour
Warranty cost	\$40	Builders markup 15 – 25%.
Permit	\$10	Extra inspection for antisiphon valve or as part of pre-drywall.
Builder margin	\$700	35% gross margin on optional features.
Total Sales Price to Customer \$2,700		

"You've got to market to builders and however you approach that. There's a marketing cost out there."

"The size of your water heater platform. Many of the smaller houses that we build have a nice little cubby compartment in the end of a closet somewhere that is 2 foot by 2 foot wide, and if you stick a 120 gallon water heater in the garage, you're going to be recreating the world in there."

"You're going to get into the framers pocket. It's going to require quite a bit bigger stand."

"You might have additional permit fees, inspections from the city." And "It's a good reason for them to increase your fees."

"If the plumbers are basically supplying and installing this panel, there's the plumber's markup for that product alone. They're going to buy the product and then mark it up before they give it to us. You've got several hands it's going to go through and each hand makes a markup."

"(Markup) from the manufacturer to the distributor, the distributor to the plumber, the plumber to us."

ISSUE: Solar water heating is still too expensive. It needs to be financially attractive to everyone.

SOLUTION: Respondents agreed that solar water heating needs to be financially attractive to builders, contractors, and homeowners. Builders and contractors wanted rebates from the manufacturer. Some felt that homeowners should get a tax credit for solar water heaters. To resolve this issue, develop a rebate program modeled on the successful approaches of established products such as windows, appliances, and insulation materials. The size and type of rebate will vary depending on whether the builder or trade contractor purchases the product. Manufacturer-provided rebates demonstrate the manufacturer's confidence in their product; it's part of a business-based decision-making process. Rebates may also be geared to reward customers that promptly pay their invoices. This is frequently done for lumber and plumbing products. Government-provided rebates are seen by some as a prop to create an artificial market for products that would not otherwise be successful.

WHAT TYPE OF REBATES DO YOU WANT FOR SOLAR WATER HEATING?	
GROUP A	GROUP B
• Government tax credit to the homeowner • Manufacturer rebate to the builder	• Manufacturer to builder • 10% for specifier/trade contractor • Hold prices for a period of time • Donate products to model homes or give 50% rebate • Don't expect federal government rebates • 3–5% rebate to builder on production homes

“Rebates vary on quantity. If you’re going to buy 100 or 5,000, it’s going to make a big difference...If I go back to the manufacturer and say I have 100 homes, can you make me a deal if I put them in every single home, then it’s not going to be an option.”

“I’m very aggressive when it comes to rebates. I see the builders are getting more and more aggressive on rebates. It could make the difference of choosing one manufacturer over another.”

“What they’re saying is if you buy my product, I’m going to rebate back to you 5% or 2% or 10%. That’s normally from manufacturer to builder...I would say 3% to 5% on production homes and 10% to 50% on models.”

“I recall when we were doing these before, the tax breaks were the real hot button that caused people to do it...the federal government gives you an exemption for a solar water heater without the reason of an oil or gas shortage? If they did, they would be going against the electric and gas manufacturer. That would be unfair.”

ISSUE: Who is going to purchase all the solar water heating system parts and components?

SOLUTION: The manufacturer should supply all of the parts, which should be compatible with standard replacement parts. The contractor would purchase the parts from a supplier, and take responsibility for purchasing all parts, just in time for installation.

"The ideal situation would be the tank, the panels, the pump, the sensors, the controller and the valve all in one."

"More than likely, it's going to be purchased by the contractor through a wholesale house. We have no place as a builder to store it...We (builders) don't want to handle it because then we realize we're missing a valve. We're not prepared to deal with that type of inventory."

"When something goes wrong, they're (contractors) the ones who are going to have to deal with getting replacement parts."

"Being in the installation end of it, a couple of years down the road if something doesn't work can you get the part to replace it? We're talking about getting with the manufacturers before the fact and making sure that there is a uniform design for your brackets, for your connections, for your fastening and weather protection."

ISSUE: It's a new product and requires additional builder and contractor warranties because of the increased risk. This adds to the cost.

SOLUTION: Provide a comprehensive manufacturer warranty to reduce the perceived risk of liability to builders and contractors. The warranty should be better than the warranty for conventional products. Respondents think it should have a no dollar limit with a ten year warranty on the collector; 5-6 years on the tank; and one to two years on the labor and materials. The warranty should be backed up by a third-party underwriter and should address labor and materials. In addition, builders are likely to include their own warranty to cover any future costs associated with call backs. This needs to be considered in the price of the unit or as part of the manufacturer support.

WHAT TYPE OF WARRANTY DOES SOLAR WATER HEATING NEED?	
GROUP A	GROUP B
• No dollar limit • 10 years on the collector • 5 years for tanks • 1 year for other materials • 1-2 years on work	• Must be better than warranties for conventional products – 2 years parts – 6 years tank • Independent underwriter for insurance

"This is a deferred cost...so down the road when I have to warranty the product, I've got to pull the money to get people to take care of it. The warranty covers labor and materials for only so long. There is a point where they cover just the material. Then one of two things happens. Either the homebuyer covers that labor costs or the builder steps in because of the good will."

"None of the builders are the same. Other builders will go above and beyond and stand behind it if for some reason the manufacturer doesn't come through. Builders will generally have some of their costs set aside for warrantee for the stuff we're not going to be able to get from the trades. The homeowner isn't going to pay for it, so we have to. On this particular item, I don't

know. I'm trying to be fair on this. It's a new product. You say it meets all these things, but it's still new. We'll probably want to protect ourselves a little more."

"What about a NDL from the manufacturer? That means a no dollar limit warrantee that they give. In roofing it works for 10 years. In 10 years, if there is any problems with the product, then the manufacturer foots the bill. That's what NDL stands for – no dollar limit. Let's say Joe Roofer went out of business. They could call another licensed and approved applicator, go out, fix it for no cost to the builder."

"The companies with the NDL warranty, the guys that really believe in their product, will say, 'Hey, whatever it costs you to go there, we'll pay you.' That's great."

ISSUE: Installing solar water heating requires an additional contractor.

SOLUTION: Plumbers feel that they have the tools and skills to install solar water heating. They did not view solar water heating installation as difficult; however, they noted that it would include some extra work. Builders, roofers, and HOA/CC&R representatives agreed that plumbers were best suited to do the installations.

"So, all you're doing is running the piping and setting the solar system on the roof. The other you've already got added to your initial bid. So, how much did it cost you to run the pipes and put the panel on the roof? That's what you're adding to the job...I'm looking at 2 hours for piping, one man. Then I'm looking at 2 men for 4 hours to load it up and make the connections...I figure 10 [hours]...above and beyond what you were already going to do."

"The plumber should install the system itself. Anything to do with the roofing, of course, should be done by the roofer. We'd also have some things installed by the framer. But the plumber should install the water piping. And of course the plumber should install the panel and make the connections."

ISSUE: The solar water heating industry lacks the infrastructure, trained labor pool, and support mechanisms to instill builder and trade contractor confidence.

SOLUTION: Production builders expect comprehensive manufacturer support programs for all building products they use. This support effort must extend from installer training and in-field technical support before the sale occurs to comprehensive maintenance and warranty programs for homeowners. Builders expect the manufacturer of an installation-sensitive product like a solar water heater to provide precise installation instructions that work in the real world. A technical representative must make regular field visits for problem solving and ongoing training of builder construction and sales staff as well as trade contractors. In addition to being "on call" for emergencies, the technical representative must periodically attend the builders' production meetings and tour job sites without the builder requesting it. Third-party certification of installers would increase builder confidence. Homeowner maintenance materials should include videos and printed material.

WHAT TYPES OF ADDITIONAL MANUFACTURER SUPPORT AND TRAINING ARE NECESSARY FOR INTEGRATION OF PRODUCTS?	
GROUP A	GROUP B
• Stand behind product • No dollar limit warranty • Availability of parts • Sole manufacturer of all parts with several suppliers • Manufacturer specifications • Sizing instructions • Do's and don't's related to installation • Installation • Service training – How to take care of the warranty items • Sales staff training • Field staff training	• Weekly in-person problem-solving call • Availability • Maintenance information for homeowner packages • On-the-job training • Safety School/OSHA • Training manuals (with specific product/approach)

“We’re looking out for marketing. We’re looking for manufacturer rebates, maybe co-op on advertising, things like this to help deal with some of those expenses, for them to give us that kind of support.”

“Our first concern is manufacturer cooperation.”

“Especially being new because they are going to have to educate those inspectors.”

“As the builder, I need information on how that homeowner is to maintain that item. The warranty books and videos that we put out for the home buyers...”

“For instance, TrusJoist. They have a department and they’ll come out and meet with our engineers to help them lay out the (system). They know their own product. It’s cost-effective for the builder because we’re going to get the best out of the product.”

“I expect weekly calls from my vendors. I get weekly calls from my vendors now.”

“A great idea (would be) to make sure that there was, and I don’t know if we said 24 hour, but a tech support line that you could call at any given time...”

ISSUE: Having a solar collector on the roof means more roof penetrations and the possibility of leaking.

SOLUTION: Use a curb and cricket installation like the one used with a skylight to raise the solar panel several inches above the roof deck to allow room for flashing and to divert water. Only a small penetration of the roof deck directly below the solar collector for the supply and return water lines would be needed. The piping is put in early in the process and capped off for later access. The solar panel should have an integral counter flashing that fits above and outside the curb flashing. The roofing, typically tile, is installed after the solar collector installation is completed.

"The reason we're building it up and flashing it is so it won't get water underneath it. It goes around it."

"What having the curb allows us to do is move the water around the sides. The flashing would be on the sides of the curb."

"The in and out lines could be stuck down on the bottom side of this panel. Provide a person with a layout sheet and they know right where to drill the two holes."

ISSUE: The placement of the solar collector on the roof can create aesthetic and performance issues. Trade contractors need to know precisely where and how to install the system on a home and which homes in a community are suitable for an SWH installation.

SOLUTION: The manufacturer should provide detailed specifications for placement of the solar collector on the roof. They should provide alternative solutions for various elevations and site orientations. Builders should then provide several architect-approved locations on each home design for solar collector installation. The approved locations would be indicated on small blueprints or cut sheets with elevation drawings of the home provided to the trade contractor at the time the work is awarded. The cut sheets would indicate the distance the unit should be from a clear reference point such as a ridge line or gable. Homes that are on lots that are not well oriented for solar performance should not be offered with a solar water heater unless there is another solution. Builders fear that their customers will find the SWHs ineffective and share this information with their neighbors and friends.

HOW SHOULD CONTRACTORS KNOW WHERE TO PLACE COLLECTORS ON THE ROOF?	
GROUP A	GROUP B
• Manufacturer and builder provide specifications	• Builders do not want plumbers and roofers to select the location • Two to four alternative locations needed • Varies by elevation, model, and location on lot

"One thing I would be concerned about is that it got installed on the right place on the home."

“I would tell my builder that the problem is his and I want him to tell me where he wants us to mount that unit.”

“You need specific measurements, just like you do with anything else. You know where a door is going to go, where a toilet is going to go.”

“To make it a lot easier to waterproof for us, it is exactly so many inches down from the top, so the courses of tile fall in just right, it makes it much (easier).”

“And some of the houses, depending upon the layout of the street, you’re just not going to be able to put solar on there and get the maximum out of it, or what people are going to expect.”

ISSUE: Many CC&Rs do not allow SWHs, and even if that is illegal they can make the process very difficult.

SOLUTION: Most states make it illegal for CC&Rs to disallow solar water heater collectors. Those who develop and enforce CC&Rs need to know this. HOAs do not create CC&Rs, the developer does, but they enforce them. They want clear instructions and teeth to enforce CC&Rs. When the developer creates the CC&Rs, sometimes 18 months before home building begins, language must be included that states the appearance, maintenance, size, system type, color, etc., that will be acceptable in the community. It is much more difficult to add language after the fact. The HOA’s enforcement capability must be clearly defined. Input should be sought from property management companies and land developers. Local public officials should establish the long-term merits of SWH before the CC&Rs are recorded.

WHAT TYPES OF INFORMATION DO CC&Rs NEED?	
GROUP A	GROUP B
• SWHs need to be allowed in communities; put rules and regulations in CC&Rs • Need information 18 months in advance • Lobby large land brokers • Allow CC&Rs to enforce maintenance	• Make SWH compatible with conventional storage tank • Put it in CC&R so the HOA can enforce it • Builder submits CC&Rs to city planner, review board, and architectural review committee early in the development process

“The CC&Rs are a recorded document that goes with the land, so therefore they’re recorded at the County Recorder’s office. Prior to that time, the builders or the developers can do pretty much whatever they want. And it’s all done prior to the first closing of the first home...It’s real tough when you’ve already got them established. These become public documents that are attached to the project...They (HOAs) can go in there and with a certain percentage of the votes can make changes, but it’s real difficult. It’s real hard to do. So generally, you’re talking development stage is when this has to be addressed.”

“In the last two to four years, part of the change that we’ve seen is the builders and developers asking the management company for input before the CC&Rs are recorded because they’ve seen the light that whatever they do today has an effect long term.”

“The developer has to put the teeth in there for us to go to court. Because if we can’t go to court, then we can’t enforce anything...The CC&Rs pretty much govern that community and they can be stricter than the local building codes. They cannot be less than, but they can be stricter and require things.”

ISSUE: Solar water heating must overcome market acceptance hurdles created by past product failures.

SOLUTION: Builders expect strong, multi-faceted marketing support that would generate product awareness and help them sell homes that include solar water heating. There was agreement that marketing strategies should be tailored to the move-up home buyer market segment. Incentives would be needed to get builders to include the product in their model homes. Builders are willing to feature building products in their advertising if the product manufacturer shares the cost. Hands-on marketing materials for use and distribution at the point of purchase would need to be provided to Realtors and the builder’s in-house sales staff.

WHAT TYPES OF MARKETING SUPPORT WOULD BE USEFUL?	
GROUP A	GROUP B
• Cooperative advertising for print, radio, and TV • Point-of-purchase brochures • Miniature displays that work to describe to customers • Incentives/sales bonuses • Technical support (1-800-TECH REP)	• Cooperative advertising • Product samples/displays just like other options • Radio spots • Model homes

“When it comes to model homes, they’ll provide a unit 50% of the cost, or sometimes even 100%. It’s advertising for them. So you’ve got model home programs, production home programs.”

“I would expect there to be a co-op in marketing. They’re going to share the marketing costs. It’s a new product.”

“It’s an upper-end community.” And “Yeah, it’s not an entry-level. It’s not a first-time home buyer.”

“They’re going to rebate me more money if I advertise this product within my sales department with displays or samples. Sometimes they will pay for a radio spot if I mention that this home is built with this product.”

“Lennox Furnaces is one that comes to mind real quickly. Lennox steps up and co-ops with builders for advertising quite a bit. And GE.”

ISSUE: There's no role for utilities other than rebates and cooperative advertising.

SOLUTION: Although respondents did not immediately perceive a role for utilities, once they learned that SRP was conducting the study, they realized that SRP could create consumer demand because of its positive image, large customer base, and built-in marketing/advertising opportunities.

WHAT ROLE SHOULD THE UTILITY PROVIDE?	
GROUP A	GROUP B
• Provide incentives/rebates • Cooperative advertising	• Uncertain due to deregulation • Offer home buyers incentives to select energy efficiency/solar water heating for selecting a certain utility

"The utility companies aren't going to credit us for using their company within the community because as soon as the home buyer comes in, they can switch over. It (deregulation) will be just like the phone companies right now."

"The only thing I could see the utility companies doing is offering an incentive to the home buyer when they sign up for a particular electric company for having these items in their home. That would help the builder sell the product to the buyer. That's looking at the future with deregulation."

"(The utility company's) name is well known, so you already have an automatic advertising system through your little mailers that you put in your bills, so you can start advertising solar applications and get people to start thinking back that way."

"I think knowing who you are, you've got a lot of advantages over just a company coming into the valley and starts selling a product."

ISSUE: Solar collectors are typically placed high on the roof where installation and maintenance are difficult.

SOLUTION: Place the solar collector somewhere other than on the roof. If the unit is placed on the roof, it should be close enough to the eaves to allow access for installation or maintenance without climbing on the roof. The manufacturer could provide prefabricated cheater boards that can be folded and unfolded to provide a path to the solar collector without damaging roof tiles or requiring their removal. To enhance safety, the cheater boards could have a non-skid surface. In addition, CC&Rs want clearly stated maintenance requirements with teeth, to enforce the upkeep of the systems.

WHAT LONG-TERM ISSUES NEED TO BE RESOLVED?	
GROUP A	GROUP B
• Include in CC&Rs	• Access (put collector on a patio roof) • Use cheater boards/plywood to walk-out/cherry picker • \$100 – 200 to remove and replace tile • Apply closer to the edge • Reasons on roof – leak, broken glass (hail/branch), maintenance of components within unit

RECOMMENDATIONS

The following recommendations are based on the summary of the roundtable on solar water heating held on behalf of SRP. The recommendations are designed to help SRP make business decisions weighing the costs and opportunities associated with developing a program that offers the solar water heating for new homes.

- (1) To integrate solar water heating into new homes, work with land developers early in the process to ensure the CC&Rs include solar water-heating specifications and language that enables maintenance enforcement.
- (2) To integrate solar water heating into new homes, prove that it has tangible benefits to homeowners so that they want solar water heaters on their homes. For the mainstream market, solar water heaters need to be cost-effective by demonstrating a positive monthly cash flow. SRP has the opportunity to create demand through consumer awareness campaigns. The first step is letting home buyers know that they have this option.
- (3) To integrate solar water heating into new homes, builders need assurance that the product will perform and that they will profit with little liability. The units must have a reasonable first cost so that builders and contractors can profit from their installation. If it cannot meet the first cost demands, the costs must be defrayed through rebates.
- (4) To integrate solar water-heating into new homes, builders and contractors should face little to no risk of liability. Performance needs to be backed up with strong warranties from the manufacturer. For example:
 - Provide a comprehensive warranty;
 - Partner with an insurance company; and
 - Provide additional guarantees from SRP that would build confidence, since SRP has positive recognition and is perceived as having deep pockets should something go wrong.

(5) To integrate solar water heating into new homes, reduce the cost of installation. Solutions for reducing these hidden costs include:

- Provide good installation instructions to reduce trade contractor time;
- Provide a prefabricated roof cricket to reduce additional framing labor;
- Provide prefabricated water heater platform (similar to an HVAC equipment pad);
- Develop uniform designs for connections and fasteners;
- Ensure that there is ample trained and qualified or certified labor.
- Have production builders install them on most homes in a community to gain economies of scale.

(6) To integrate solar water heating into new homes, make maintenance simple:

- Provide cheater boards or ladders so that qualified repairers can perform maintenance without cracking tiles;
- Make glass readily removable to reduce any repair and replacement costs;
- Provide maintenance enforcement in CC&Rs so that should maintenance be required, it can be done correctly by HOAs and not give solar water heating a bad name; and
- Manufacture the collectors so that they require little or no maintenance so that homeowners can forget they are there.

(7) To integrate solar water heating into new homes, make it attractive to builders. Sell builders on the idea through field demonstrations with opinion-leading builders and inclusion in model homes. Then back this up with marketing, training, and technical support.

Appendix C.
Salt River Project Renewable
Energy Programs Evaluation
Market Research Findings

SRP and Cambridge Systematics, Inc.

Salt River Project Renewable Energy Programs Evaluation

Market Research Findings

presented by

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Colleen Warner
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October 2, 2001



Research Topics

- Environmental Attitudes of SRP Customers
- Discrete Choice and Customer Evaluation of Renewable Energy Programs
 - EarthWise Energy
 - Solar PV Power Systems and Solar Water Heaters
 - The market potential for each of the renewable energy programs
- Customer Evaluation of SRP and its Renewables Initiatives
 - Corporate Citizenship
 - Value to the Community
 - Solar Energy and "Green Power" Programs



Project Objectives

- Analysis of customer attitudes
 - How environmentally aware and concerned are SRP customers?
 - What do customers think of the EarthWise Energy program, solar water heaters, and solar PV power systems?
- Customer choice behavior
 - What is the market potential for the three renewable energy programs?
 - What drivers will influence people's participation in the renewable energy programs?
 - What insights for marketing the programs can we identify?
- Attitudes toward Salt River Project
 - How does SRP's commitment to these renewable energy programs affect customers feelings toward SRP?



Customer Sampling – Population of Interest

- Customer strata 3 through 6
- Owners of single family homes, condos, and townhouses
- Over-sampled market segments
 - EarthWise participants
 - New and prospective homebuyers

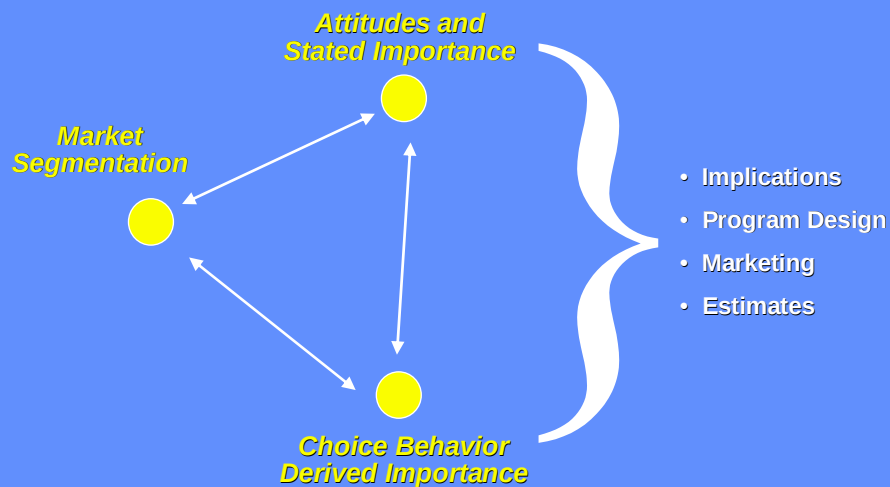


Quantitative Research Protocol

- Qualified individuals contacted and screened by phone
- Participants were mailed program descriptions and a short household questionnaire
- Participants came to one of two central-site facilities:
 - WestGroup Research, Phoenix
 - La Quinta Hotel, Mesa
- 354 participants completed self administered questionnaires (average 45 min.)



Market Assessment



Statistical Analysis Methods

- Traditional market research techniques
- Discrete choice analysis and modeling
 - Choice decision and market potential related to:
 - Program features
 - Pricing attributes
 - Customer characteristics/ market segments
 - Four customer choice models
 - EarthWise Energy
 - Solar Water heater
 - Solar PV Power Systems
 - Combined Solar PV / SWH

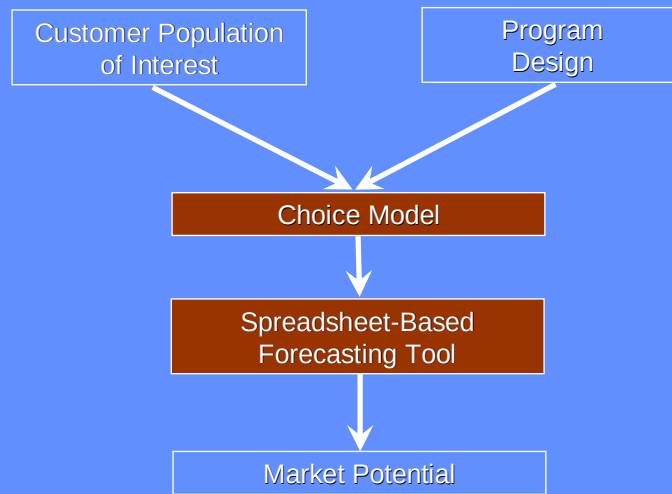


Discrete Choice Analysis

- Causal model structure
- Drivers of customer choice and market adoption
- Measures of model quality and statistical robustness
- Derived importance of each attribute on purchase decision
- Insights and implications of models on
 - Program design
 - Targeted marketing
- Evaluation of “what if” scenarios on market potential



Discrete Choice Model Application



***Significant Findings
and Implications for
Program Design and Marketing***



Significant Findings

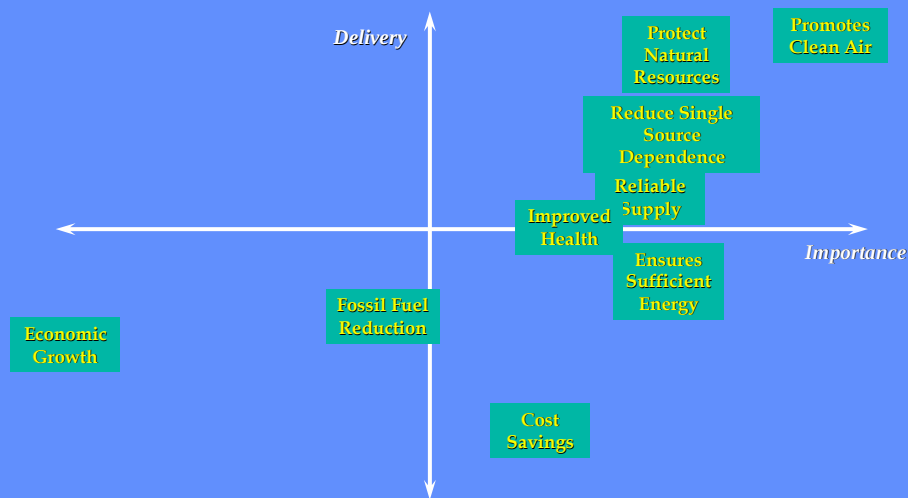
EarthWise Energy Program

- Customers who are environmentally interested and active are more likely to be EarthWise participants
- Most customers are not familiar with EarthWise Energy
 - 42 percent of customers “not very familiar”
 - 29 percent “not at all familiar”
- Market potential for current EarthWise Energy program is approximately 22,000 customers (about 7 percent of survey population)
- Enhanced familiarity, awareness, and understanding of the program are keys to increasing participation



Importance and Delivery of Benefits

EarthWise Energy



Significant Findings

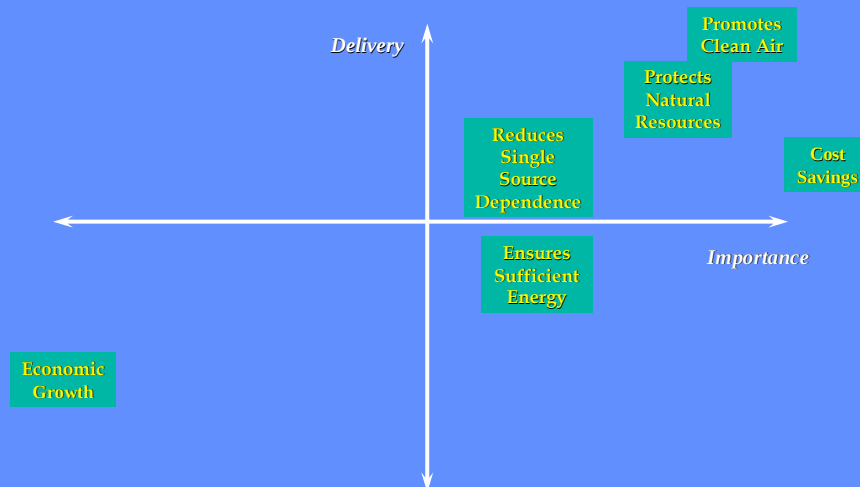
Solar Water Heaters and Solar PV Power Systems

- Customers relate environmental benefits to solar water heaters and solar PV power systems, and they respond favorably to these concepts
- But, the market potential for these systems is low for the currently anticipated cost and energy saving levels
 - 2 to 5 percent of new homebuyers based on preferred attributes and likely cost



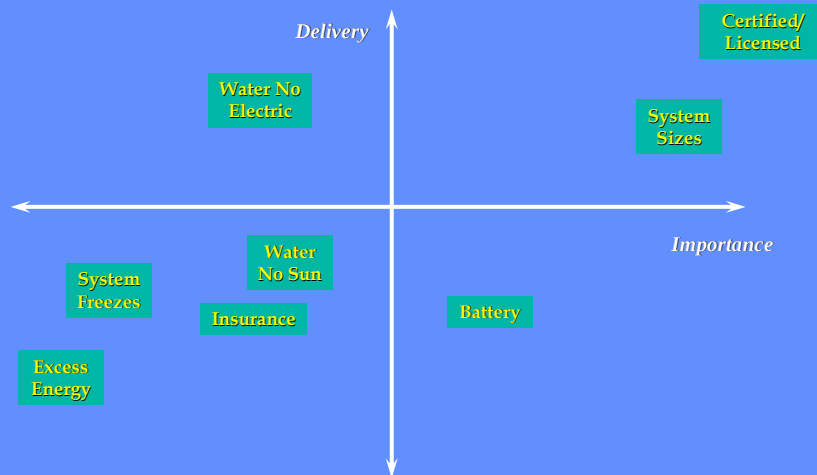
Importance and Delivery of Common Benefits

Solar PV Power Systems and Solar Water Heaters



Importance and Delivery of System Benefits

Solar PV Power Systems and Solar Water Heaters



Implications for Solar PV Power Systems and Solar Water Heaters

■ Program Design

- Home builder or subcontractor is the preferred installer
- Systems with AZ Energy Saver Home package strongly preferred
- Maintenance by authorized/certified service providers was preferred
- Longer / extended warranties strongly preferred



Implications for Solar PV Power Systems and Solar Water Heaters

- Marketing Targets
 - More mature household segments (Microvision)
 - Members of environmental organizations
 - Respondents who are willing to pay more for environmentally friendly products
 - Respondents who are familiar with EarthWise
 - Respondents with at least some college education
 - Respondents with larger homes



Significant Findings

Customer Evaluations of SRP (1 - 5 scale)

Percentage of customers rating SRP as “very good” or “excellent”

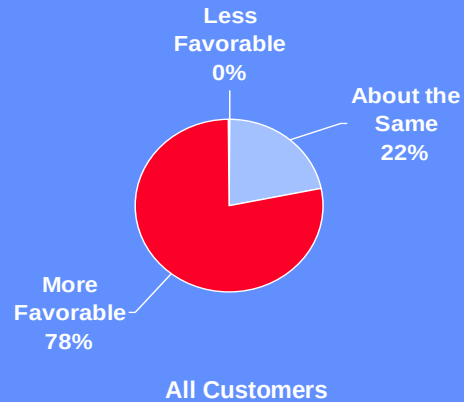
<u>Rating Measure</u>	<u>All</u>	<u>EarthWise</u>
Value to the community	81%	94%
Corporate Citizenship	66%	67%
Solar Energy/Green Power Programs	48%	59%
Leader in Environmental Management	65%	78%



Change in Opinion of SRP

Effect of Renewable Program

Now that you know that SRP is involved in developing renewable energy resources, is your opinion about SRP ...



Corporate Implications

- The market potential for EarthWise Energy is reasonably large but converting that potential to subscribers will require significant time and effort
- Despite the low market potential for solar water heaters and solar PV systems, continued R&D efforts are warranted because of:
 - their attractiveness to customers and
 - their potential to positively affect SRP's image



Corporate Implications

- When customers are exposed to and educated about SRP's renewable energy programs, we get a potential "lift" in customers' evaluations of
 - Environmental activities and
 - Value to the community.



Presentation Outline

1. Environmental Attitudes of SRP Customers
2. Evaluation of EarthWise Energy
3. Evaluation of SWH and Solar PV Power Systems
4. Market Potential of Renewable Energy Programs
5. Customer Choice of EarthWise Energy
6. Customer Choice of SWH and Solar PV Power Systems
7. Customer Attitudes Toward SRP and its Renewable Energy Investments



Topic 1.

Environmental Attitudes of SRP Customers



Environmental Attitudes

Survey Measures

- Attitudinal statement level of agreement
 - How much do customers consider the environment in their product purchases?
 - How do customers react to issues that have been linked to environmental product purchase behavior?
- Are customers members of environmentally oriented organizations?
- How important do customers say the different renewable program benefits are?



Environmental Attitudes of SRP Customers

Summary - EarthWise Energy Program

- EarthWise Energy customers are more environmentally interested and active than other customers
 - 40 percent of EarthWise Energy customers participate in environmental groups; 10 percent of other customers do so
 - Higher levels of purchasing environmentally friendly products
 - Assign higher importance to renewable energy benefits
- Future EarthWise marketing may benefit from tailored messages
 - Transactional customers - higher levels of purchasing environmentally friendly products and environmental activism
 - Relationship customers - assign higher importance to renewable energy benefits



Environmental Attitudes of SRP Customers

Summary - Solar PV Systems and Solar Water Heaters

- New homebuyers have the “right” stated attitudes and priorities for renewable programs...
- But they have not shown the follow-through in purchasing environmentally friendly products and environmental activism



Topic 2

Evaluation of Earthwise Energy



Renewable Energy Program Evaluation

Survey Measures

- How important do customers say the different program-specific benefits are?
- Based on what they have learned of these products, how well do customers believe the renewable programs deliver the potential benefits?
- How do customers perceive the renewable program concepts and Arizona Energy Saver Home?
- How willing do customers say they are to purchase the renewable programs?
- Based on their tradeoffs among different potential programs, how do customers value different program attributes?



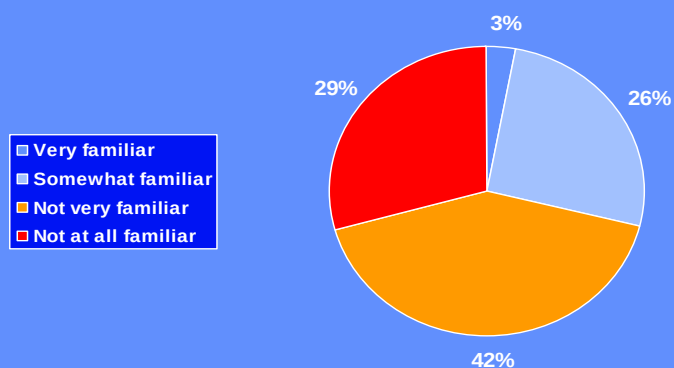
Evaluation of Earthwise Energy

Summary

- Customers see environmental benefit and overall value in the EarthWise Energy Program ...
- But, they are not familiar with it
 - Only 3 percent of customers said they were “very familiar” with the program
 - 26 percent said they were “somewhat familiar” with it



Familiarity With SRP's Earthwise Program



All Customers



Topic 3

Evaluation of Solar Water Heaters and Solar PV Power Systems



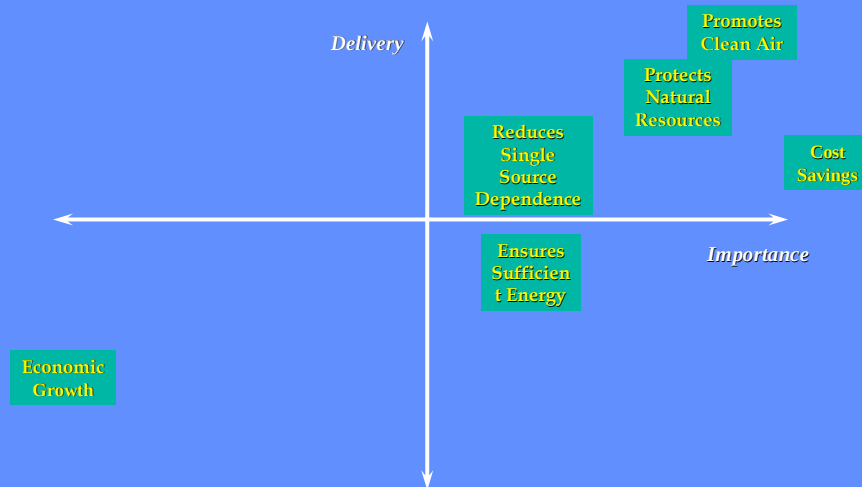
Evaluation of Solar PV and Solar Water Heaters *Summary*

- Customers see environmental benefit in solar water heaters and solar PV power systems, and respond positively toward these systems
- Customers like solar water heaters more than solar PV power systems
- Customers like the “Arizona Energy Saver Home” concept more than either solar system



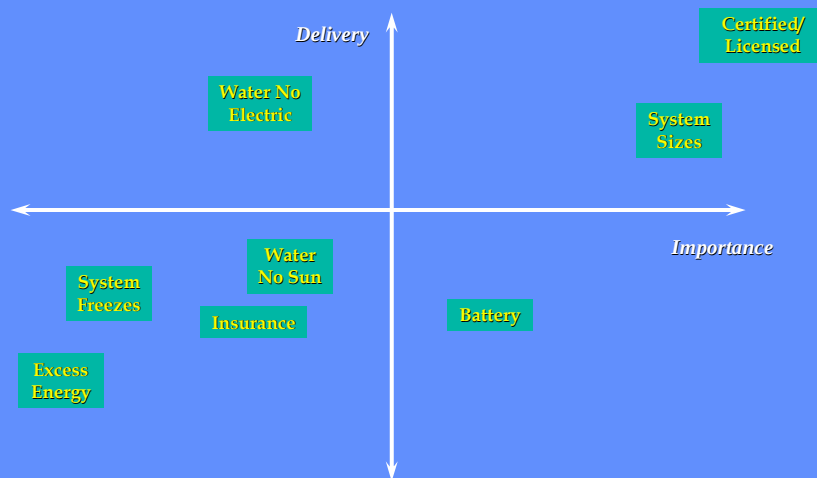
Importance and Delivery of Common Benefits

Solar PV Power Systems and Solar Water Heaters



Importance and Delivery of System Benefits

Solar PV Power Systems and Solar Water Heaters



Topic 4

Market Potential of Renewable Energy Programs



Market Potential and Customer Choices

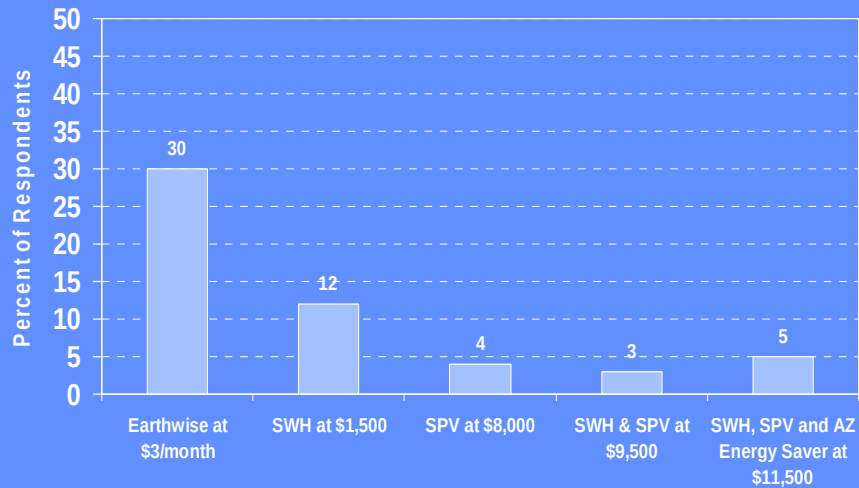
Survey Measures

- Stated purchase intentions
- Discrete choice analysis
 - Earthwise Energy Program
 - Solar Water Heaters
 - Solar PV Power Systems



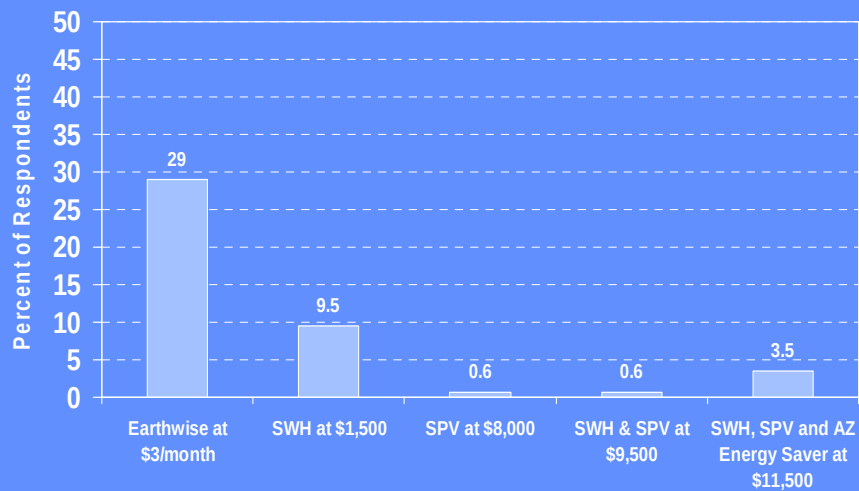
Purchase Intent by Program

Percent Who Would "Definitely Purchase" - All Respondents

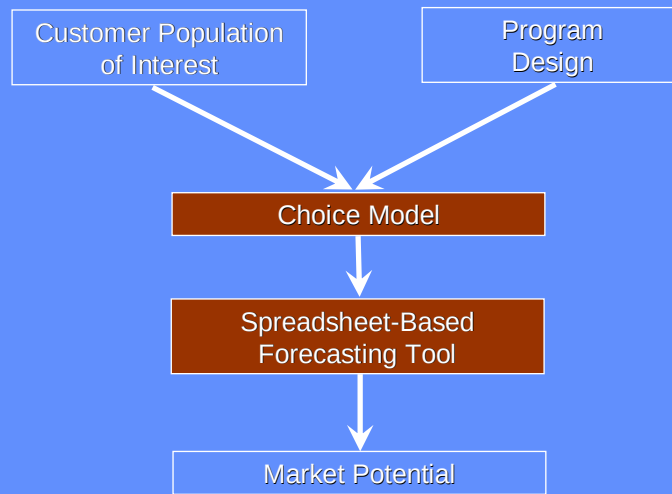


Purchase Intent by Program

Percent Who Would "Definitely Purchase" - New Homebuyers

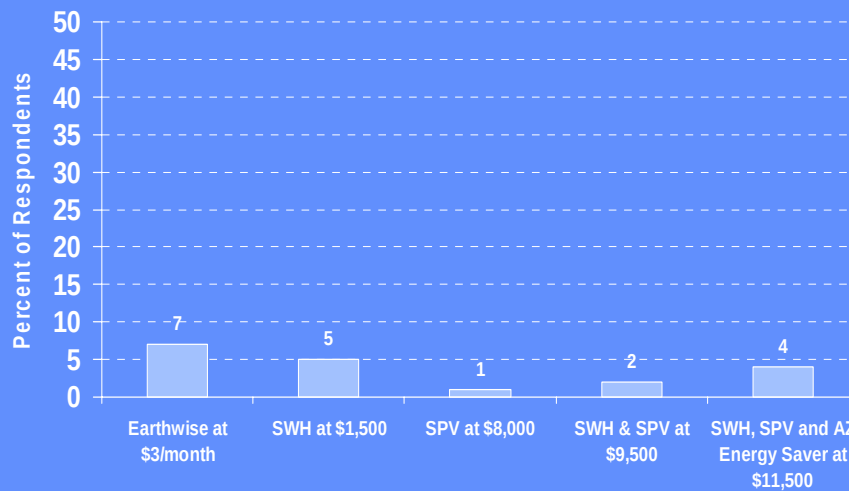


Discrete Choice Model Application



Discrete Choice Model Forecasts by Program

Model Derived Market Potential – SPV & SWH New Homebuyers Only



Topic 5

Customer Choice of EarthWise Energy



Discrete Choice - Earthwise Energy Program

Model Attributes

- Program Features
 - Electricity provider
 - Program commitment
 - Impact on monthly bill
 - Users of renewable energy
 - Reward for participation
 - Types of renewable energy
- Customer Characteristics
 - Socioeconomics
 - SRP customer information



Discrete Choice - Earthwise Program

Insights from the Modeling Effort - Electricity Provider

- Four electricity provider options:
 - SRP
 - Other local utility
 - National utility
 - Local cable company
- SRP is strongly preferred over other options
- Other utility companies preferred over cable company



Discrete Choice - Earthwise Program

Insights from the Modeling Effort - Program Commitment

- Three program commitment options:
 - Already committed renewable energy plants
 - R&D programs on renewable energy
 - Construction of new power plants if enough funds are raised
- Already committed plants and R&D programs strongly preferred over the option of new plants provided enough funds



Discrete Choice - Earthwise Program

Insights from the Modeling Effort - Effect on Electricity Bill

- Cost of program participation ranged from \$0 to \$9 per month
- Proper sensitivity to monthly cost of EarthWise
- The cost elasticity implies that higher monthly fees will result in lower participation rates



Discrete Choice - Earthwise Program

Insights from the Modeling Effort - Users of the Renewable Energy

- Users of renewable energy options:
 - Local customers
 - Local and out-of-state customers
- Customers prefer slightly that local customers only use the renewable energy



Discrete Choice - Earthwise Program

Insights from the Modeling Effort - Reward for Participation

- Reward for participation options:
 - Energy saving products
 - No individual reward
 - Personal recognition
- Customers do not value the reward of products any higher than no reward
- Customers are much less interested in the personal recognition reward



Discrete Choice - Earthwise Program

Insights from the Modeling Effort - Type(s) of Renewable Energy

- Options for the type of renewable energy:
 - Solar only
 - Landfill gas only
 - Small hydroelectric only
 - Solar and landfill gas
 - Solar and small hydroelectric
 - Solar, landfill gas, and small hydroelectric
 - Solar, landfill gas, small hydro, and out-of-state wind
- The three power and four power combinations preferred
- Reliance on individual sources least attractive
- Solar preferred over landfill gas and hydro power



Discrete Choice - Earthwise Program

Insights from the Modeling Effort - Customer Characteristics

- Market segments - Earthwise preferred by:
 - More mature household segments (Microvision)
 - Members of environmental organizations
 - Respondents who are willing to pay more for environmentally friendly products
- Socioeconomic characteristics - Earthwise preferred by:
 - Households without children
 - Older respondents & non-singles
 - Women familiar with the program
 - Respondents in the Central and Western metering districts



Topic 6

Customer Choice of Solar Water Heaters and Solar PV Power Systems



Discrete Choice - Solar PV and Water Heaters

Model Attributes

- Program Features
 - System installer
 - Bundled home package option
 - System size (solar PV)
 - System cost and annual energy cost savings
 - System maintenance and service
 - System warrantee
- Customer Characteristics
 - Socioeconomics
 - SRP customer information



Discrete Choice - Solar PV and Water Heaters

Insights from the Modeling Effort - System Installer

- System installation options:
 - Home builder or subcontractor that is a certified installer
 - Authorized dealer / installer
 - Independent certified installer
- For both types of systems, the home builder or a subcontractor was the preferred installer
- Independent certified installers were the least attractive



Discrete Choice - Solar PV and Water Heaters

Insights from the Modeling Effort - Bundled Home Packages

- Home package options:
 - Standard home builder's package with one or both of the systems
 - Arizona Energy Saver Home Package with one or both of the systems
- Systems with the Arizona Energy Saver Home Package were strongly preferred
- Combined Solar PV / Solar Water Heater systems were preferred slightly more than individual systems



Discrete Choice - Solar PV Power Systems

Insights from the Modeling Effort - System Size

- System size options:
 - 3 kW solar power system
 - 2 kW solar power system
 - 1 kW solar power system
- If price were not an issue, customers would prefer the larger systems



Discrete Choice - Solar PV Power Systems

Insights from the Modeling Effort - System Cost and Savings

- Sensitivity to additional home costs and mortgage add-on
 - Solar PV system costs from \$5,000 to \$10,000 per kW
 - Solar water heater costs from \$1,500 to \$3,000
- Sensitivity to energy savings
 - Solar PV system monthly savings from \$15 to \$22 per kW
 - Solar water heater savings from \$5 to \$15
- The impact of the additional home costs are slightly more than the impact of the monthly savings



Discrete Choice - Solar PV and Water Heaters

Insights from the Modeling Effort - System Maintenance

- System maintenance options:
 - Local solar products company that provides service
 - Authorized dealer / installer / service provider
 - Independent certified installer / service provider
 - SRP certified contractor / service provider
- No significant differences for solar water heaters
- For solar PV systems, the local solar products company was less preferred than the other options, which were all viewed about the same in terms of attractiveness



Discrete Choice - Solar PV and Water Heaters

Insights from the Modeling Effort - System Warrantee

- System warrantee options:
 - Standard 3 year warrantee plus extended 5 year warrantee
 - Standard 3 year warrantee
 - Standard 1 year warrantee plus extended 5 year warrantee
 - Standard 1 year warrantee
 - Annual new home warrantee package
- Annual new home warrantee package least preferred
- Longer warranties are preferred for both systems (strongly preferred for solar water heaters)



Discrete Choice - Solar PV and Water Heaters

Insights from the Modeling Effort - Customer Characteristics

- Market segments - Solar PV and Solar Water Heaters preferred by:
 - More mature household segments (Microvision)
 - Members of environmental organizations
 - Respondents who are willing to pay more for environmentally friendly products
 - Respondents who are familiar with Earthwise Energy
- Socioeconomic characteristics - Solar PV Systems and Solar Water Heaters preferred by:
 - Respondents with at least some college education
 - Respondents with larger homes (bedrooms, square footage estimates)

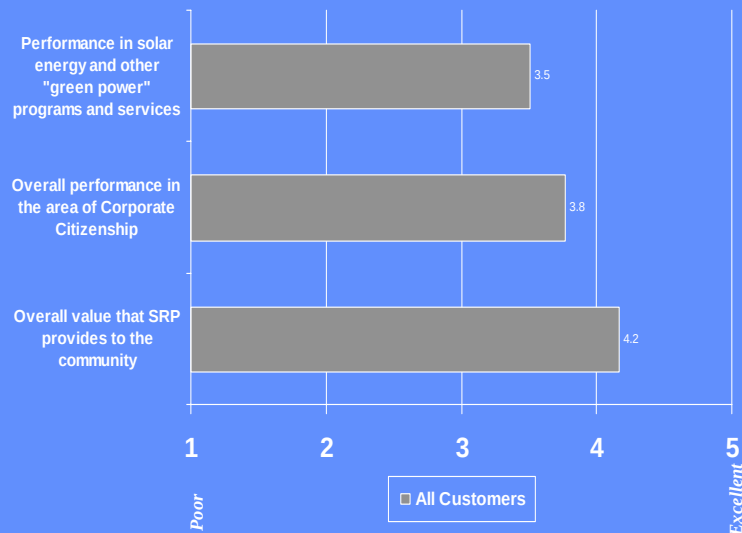


Topic 7

Customer Attitudes Toward SRP and its Renewable Energy Investments

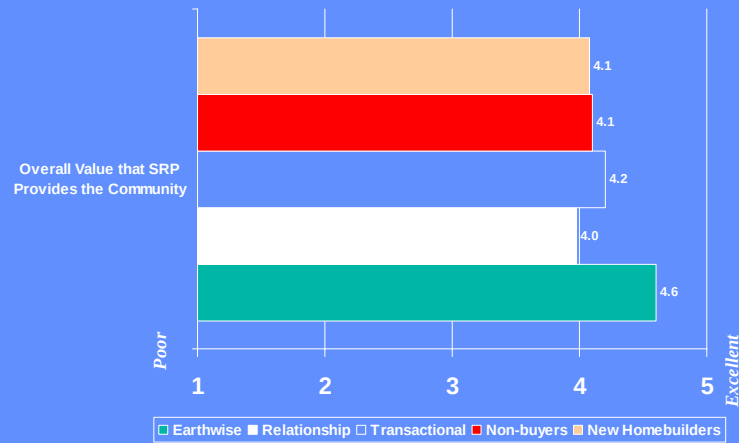


SRP Company Evaluation



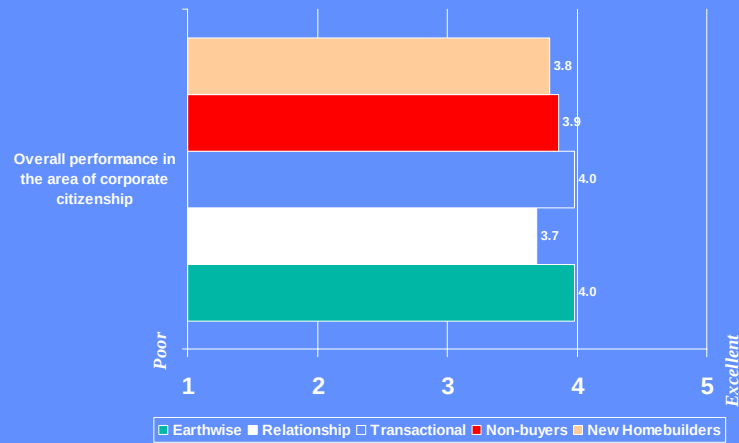
SRP Company Evaluation

SRP's Value to The Community



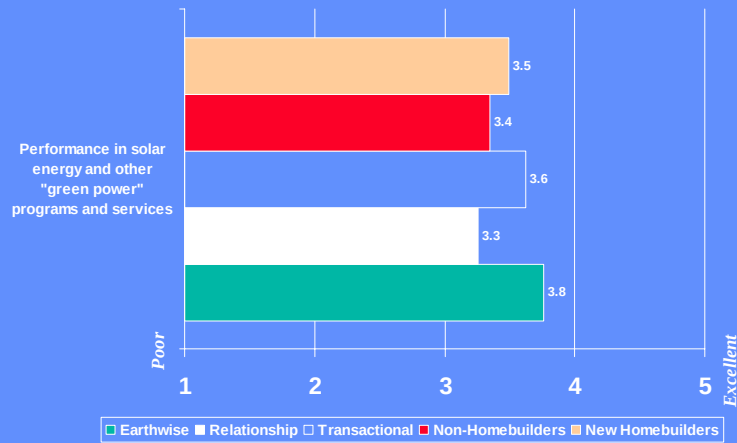
SRP Company Evaluation

SRP's Corporate Citizenship

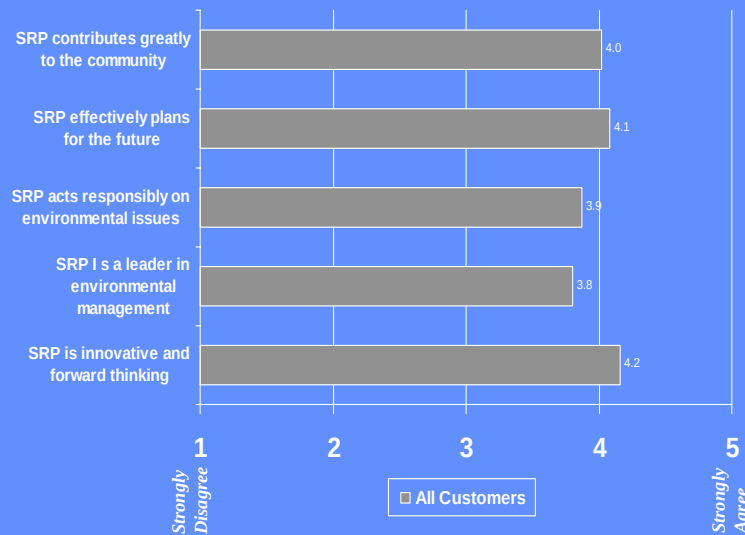


SRP Company Evaluation

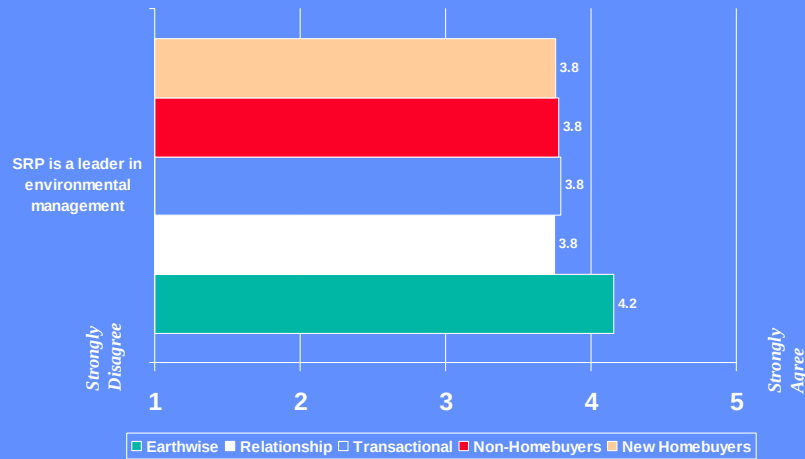
SRP's Solar Energy and Other "Green Power" Programs



Feelings Toward SRP



Feelings Toward SRP



Change in Opinion of SRP

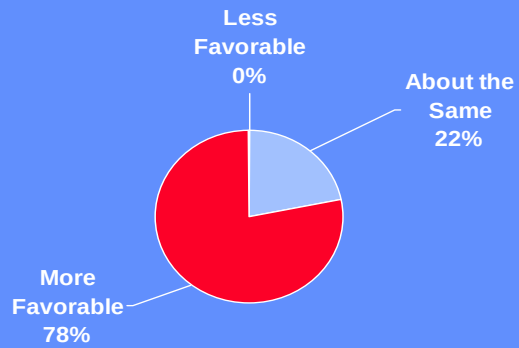
- The final question of the survey asked respondents:
 - Now that you know that SRP is involved in developing renewable energy resources, is your opinion about SRP...
 - More favorable
 - About the same
 - Less favorable



Change in Opinion of SRP

Effect of Renewable Program

Now that you know that SRP is involved in developing renewable energy resources, is your opinion about SRP ...



All Customers



Appendix D. Records of Technology Development Meetings

SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH Design Update May 31, 2001
in Albuquerque, NM

- **Project Design Criteria**

Roof Integration (simple / low cost)

Reliable (simple) and Safe

Performance ($\geq 60\%$ Solar Fraction Annual)
(Roof angle: 18.5 Degrees: 4/12 pitch or
23.9 Degrees: 5/12 pitch)

Low Cost (<\$2000 installed)



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 4 (and beyond) DESIGN
Design and Manufacturing Attributes

2-piece unit (collector & tank)

Adaptability – absorber size, tank size, plumb
config.
framewall collector – structural element

Reduced Weight - ~total wt 235#, eliminate
shipment damage

Assembly/Installation - no crane needed ...



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 4 (and beyond) DESIGN
Design and Manufacturing Attributes

2-piece unit (collector & tank)

Shipment – increased packing density,
30 units / van (from JAX)
(\$50 / unit)



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 3 & RITH 4 DESIGNS

<u>Parameter</u>	<u>RITH 3</u>	<u>RITH 4</u>
Sizes:		
absorber	2.85 m² (30.7 ft²)	2.67 m² (28.7 ft²)
glazing	84" x 60" (7 ft x 5 ft)	46" x 96" (4 ft x 8 ft)
tank	72 gallons	69 gallons
O.D.	18 inches	16 inches
Length	64 inches	76 inches



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 3 & RITH 4 DESIGNS

<u>Parameter</u>		<u>RITH 3</u>	<u>RITH 4</u>
Sizes:	complete package	108 inches	135 inches
Weights	wt. dry	400#	235#
	wt. wet	1000#	810#
Load	roof load	43# / ft²	~35# / ft²



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 3 & RITH 4 DESIGNS

<u>Parameter</u>		<u>RITH 3</u>	<u>RITH 4</u>
Economics			
	Solar Fraction		
	Energy	60%	60%
	Elec	64%	64%
	\$ Saved	\$181	\$181
	Gas	59%	59%
	\$ Saved	\$135	\$135



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH (2-piece) Manuf Costs – Assumes ELI Manuf

<u>Units Annual Produced</u>	<u>Costs</u>
4 units (current method) Manuf Conditions, etc.	(per unit)

Fin-Tube Supplied by SNL \$3K

**Each unit “hand/custom” built
with existing ELI equipment & personnel**

Unit Cost \$6.0K



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH (2-piece) Manuf Costs – Assumes ELI Manuf

<u>Units Annual Produced</u>	<u>Costs</u>
5 - 50 units	

Capital Equip & Personnel Required

Laser Welder Material Handling	\$70K
Foam Insulation Unit & Mold	\$65K
T-Drill Upgrade for SS Collector	\$ 3K
SS Brazing Table / Fixture	\$ 2K
1 shop employee (burdened)	\$30K

Unit Cost \$3.5K



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH (2-piece) Manuf Costs – Assumes ELI Manuf

<u>Units Annual Produced</u>	<u>Costs</u>
51 - 250 units	
Capital Equip & Personnel Required	
Automatic Chop Saw	\$40K
+1 shop employee (burdened)	\$30K
Unit Cost	\$2.2K



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH (2-piece) Manuf Costs – Assumes ELI Manuf

<u>Units Annual Produced</u>	<u>Costs</u>
251 - 500 units	
Capital Equip & Personnel Required	
+1 shop employee (burdened)	\$30K
(3 dedicated shop employees for RITH)	
Raw Material Cost Break at This Volume ...	
Unit Cost	\$1.2K



SRP / ELI / Sandia Solar Domestic Water Heating Project

RITH (2-piece) Manuf Costs – Assumes ELI Manuf Units Annual Produced Costs

501 - 1000 units

Capital Equip & Personnel Required

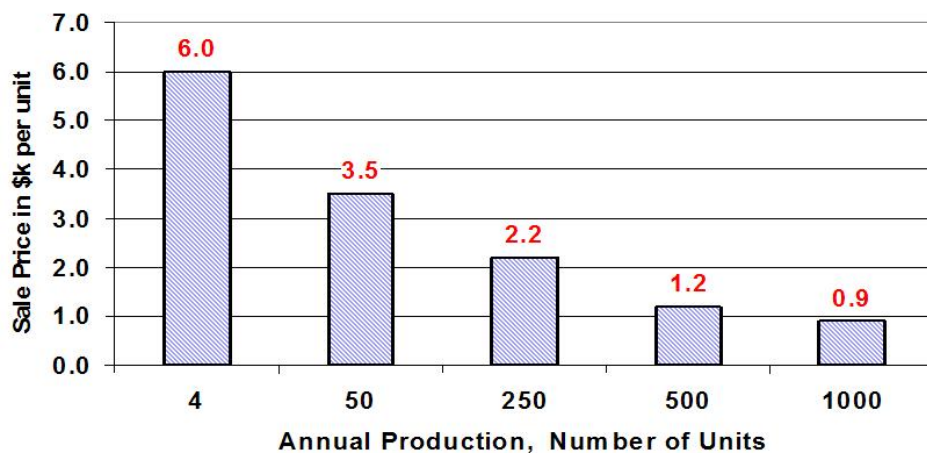
+3 shop employee (burdened)	\$90K
(Total 6 dedicated shop employees for RITH)	
+1 Shop Foreman	\$51K
+3 Admin	\$110K
Relocate ELI R&D	\$75K

Unit Cost \$0.9K



SRP / ELI / Sandia Solar Domestic Water Heating Project

**RITH Collector Production
Cost Projection**



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH Stagnation Data Update July 17, 2001
in Albuquerque, NM

• **Important Stagnation Parameters**

Engineering :	Absorber Area
	Tank Volume
	(and Diffuser Placement)
	Collector Package Insulation
Environmental:	Insolation
	Ambient Temperature



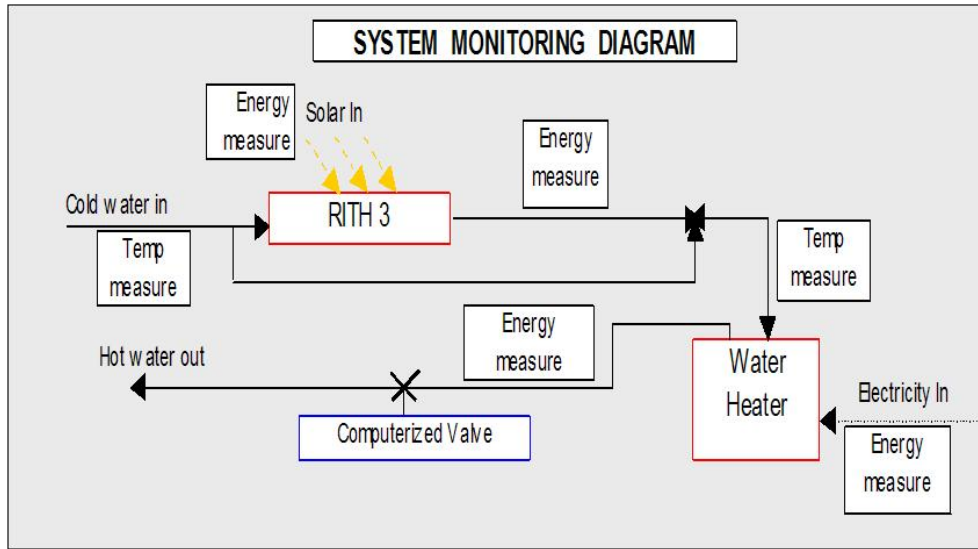
SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 3 & RITH 4⁺ DESIGNS

<u>Parameter</u>	<u>RITH 3</u>	<u>RITH 4⁺</u>
Sizes:		
absorber	2.85 m² (30.7 ft²)	2.67 m² (28.7 ft²)
glazing	84" x 60" (7 ft x 5 ft)	46" x 96" (4 ft x 8 ft)
tank	72 gallons	69 gallons
O.D.	18 inches	16 inches
Length	64 inches	76 inches

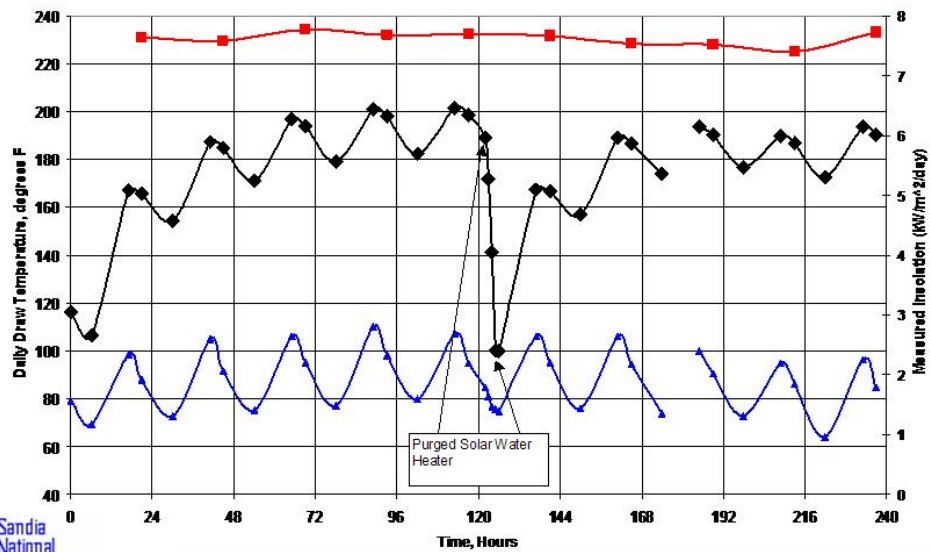


SRP / ELI / Sandia Solar Domestic Water Heating Project



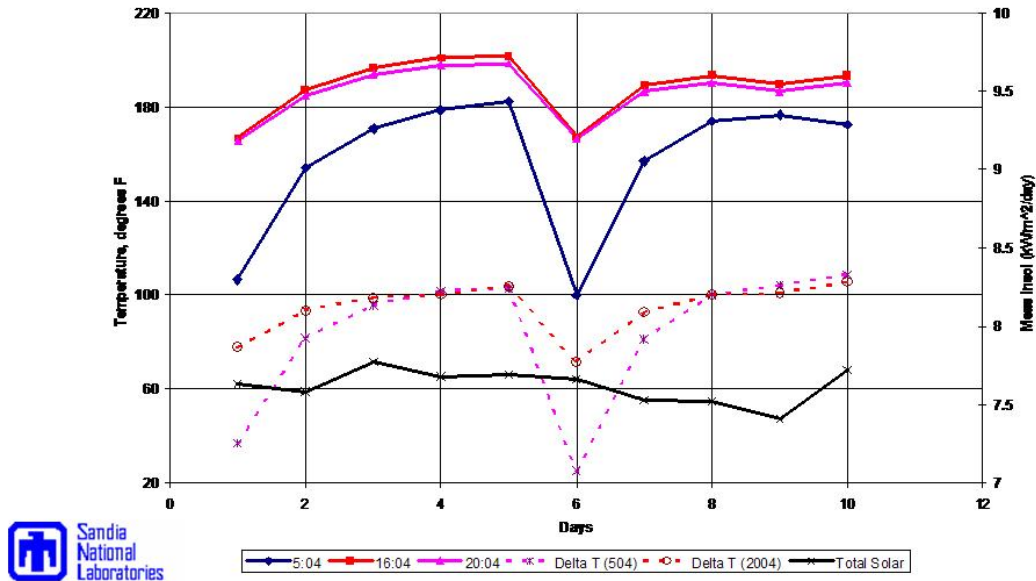
SRP / ELI / Sandia Solar Domestic Water Heating Project

RITH 3 Gold Canyon Stagnation Test Data



SRP / ELI / Sandia Solar Domestic Water Heating Project

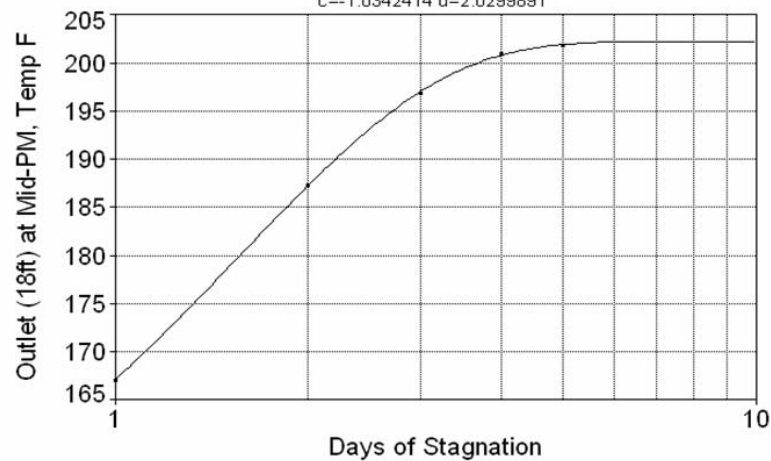
RITH 3 Gold Canyon Stagnation Test Data



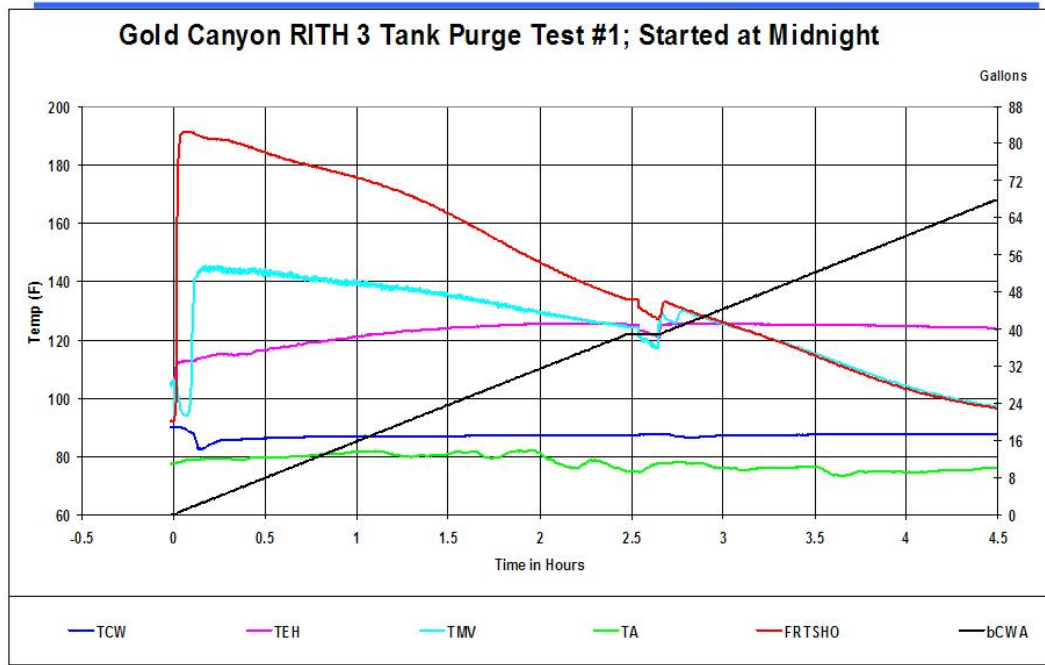
SRP / ELI / Sandia Solar Domestic Water Heating Project

RITH 3 Stagnation Test#1; Gold Canyon

$T(F)_{\text{Stagnation}} = a + 0.5b (1 + \text{erf}((\text{Day} - c)/(2^{0.5}d)))$
 $r^2 = 0.99985361$ DF Adj $r^2 = 0.99941445$ FitStdErr = 0.35060872 Fstat = 2276.7135
 $a = -20.120122$ $b = 222.24797$
 $c = -1.0342414$ $d = 2.0299891$



SRP / ELI / Sandia Solar Domestic Water Heating Project



SRP / ELI / Sandia Solar Domestic Water Heating Project

Finds and Conclusions – RITH 3 Stagnation

- Max Temp ~203F

Depends upon exposure environment (Insol & T) and
Absorber Area (RITH 4+ less)

Tank Volume (RITH 4+ Slightly less)
(and Diffuser Placement)

Collector Package Insulation

- Temperature Mixing Valve Working as
Expected; $T_{\max}$ to Water Heater $\leq 145F$



SRP / ELI / Sandia
Solar Domestic Water Heating Project

Finds and Conclusions – RITH 3 Stagnation

Measured data will enable:

Calculation of System

Overall Heat Loss Coefficient (UA)

Use of UA will better refine performance model

Allow design refinements (?) ... (Greg and Rod)

Tank Volume and Diffuser Placement

Collector Package Insulation



TECHNOLOGY OVERVIEW

A Review of the RITH Technology Development Program

Ernie Palomino, SRP
Dave Menicucci, Sandia National Labs

July 23, 2001
Albuquerque, NM



GOLD CANYON SITE SELECTED TO TEST THE FIRST UNIT IN PHOENIX

- *Calex Homes* model house
- Located about 40 miles east of Phoenix—high-end home
- 5/12 roof pitch, south facing with no obstructions
- Model home that will be unoccupied for at least one year; will allow full accessibility from testing team
- All electric home
- Located in SRP territory
- RITH visible from street
- Regional builder
- RITH located over bedroom rather than garage



GOLD CANYON INSTALLATION



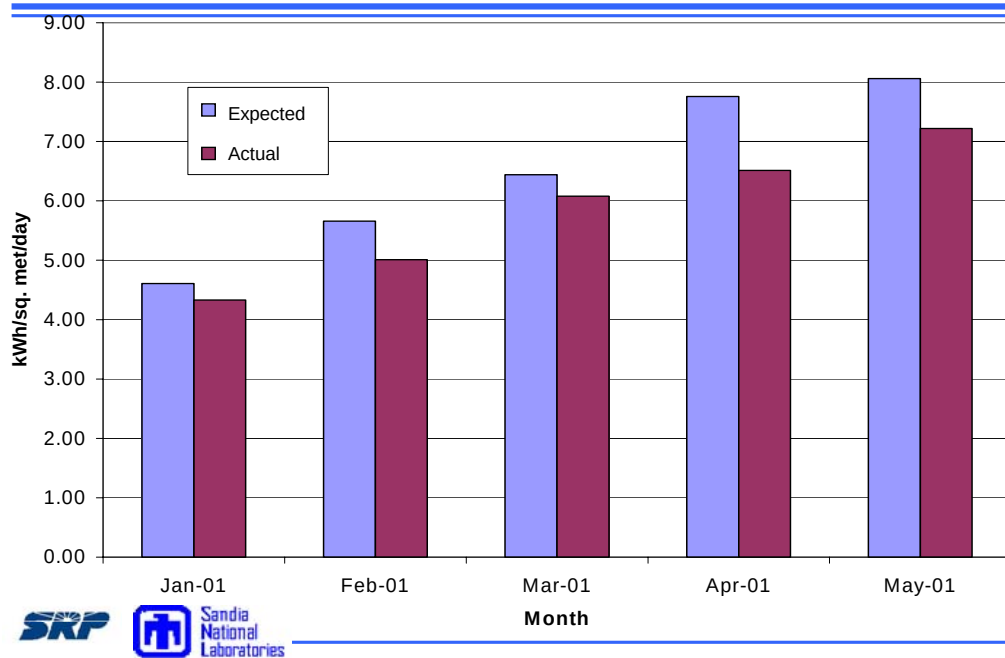
GOLD CANYON INSTALLATION



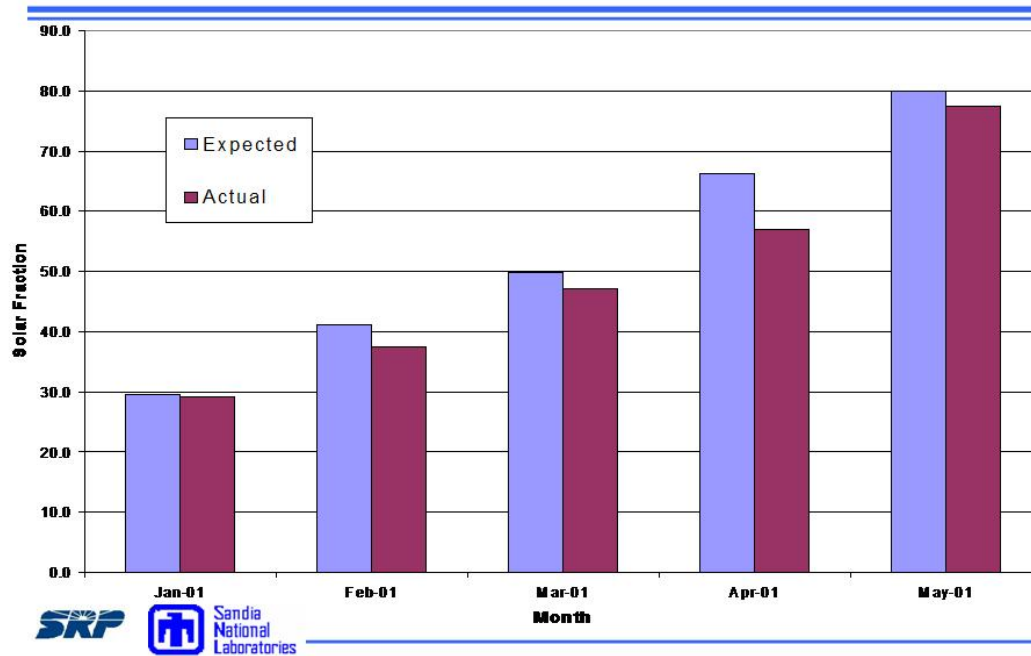
STANDARD SKYLIGHT APPLICATION



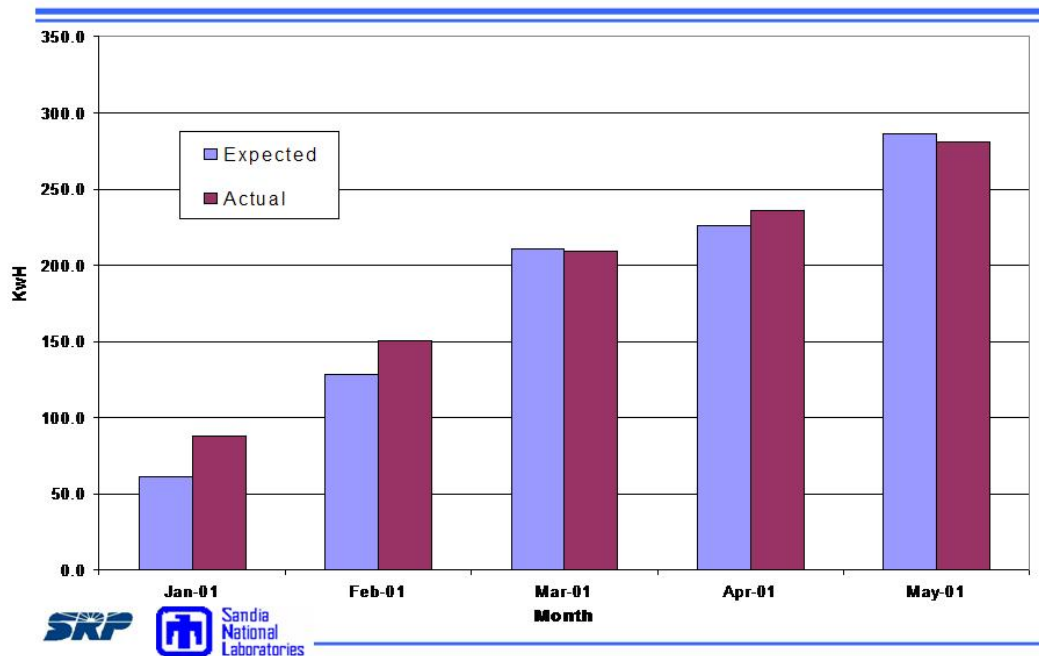
EXPECTED AND ACTUAL INSOLATION IN PHOENIX IN 2001



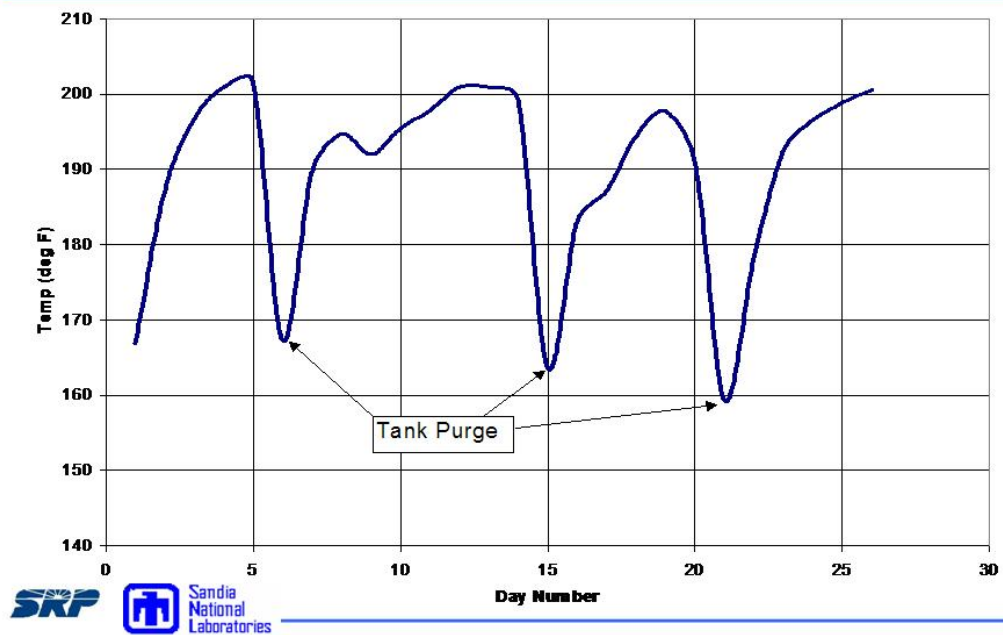
RITH FRACTION OF HOT WATER LOAD AT GOLD CANYON



RITH ENERGY PERFORMANCE AT GOLD CANYON



RITH STAGNATION PERFORMANCE



JOHNSON RANCH INSTALLATION THE SECOND RITH IN PHOENIX



OTHER OBSERVATIONS FROM RITH FIELD INSTALLATIONS

- 1) Builders and trades are enthusiastic and cooperative
- 2) Builders want to “showcase the unit”
- 3) System integrates well into the roof: looks as good or better than a roof window or skylight
- 4) When the distance between RITH and water heater is fairly long (>60 feet), treatment of the unit’s outlet piping to minimize heat loss is needed.



HOW DOES THE REAL RITH COMPARE WITH SRP’S SPECIFICATIONS?

- COST:** Initial production unit costs around \$3000/unit; production cost goal (~\$1000) achievable with reasonable production volume (>1000 units/yr.)
- PERFORMANCE:** Displaces more than 50% of the hot water load for a family of four
- RELIABILITY:** Has no moving parts; passed rigorous freeze and stagnation tests; will be manufactured in stainless steel (316L) for longevity and to prevent corrosion as seen at Civano
- AESTHETICS:** Is integrated into the roof and looks like a roof window, an accepted residential architectural feature
- INSTALLABILITY:** Has been installed by plumbers and roofers--no special trades or equipment needed



SUMMARY AND CONCLUSIONS TO THIS POINT

- 1) RITH is an example of a successful concept-to-product-development effort. This has been a successful collaboration between a utility, private company and government lab.
- 2) The development effort is close to completion. The final tasks are being negotiated. Final certified unit ready in June 2002.
- 3) The test and evaluation program has resulted in a number of significant improvements and innovations in the RITH design. A patent for RITH and one for tooling are pending.
- 4) The test and evaluation program has been time consuming and has encountered unexpected events, but has resulted in a unique product.



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH Design and Manuf Update August 29, 2001
in Jacksonville, FL

• **Important Design Issues:**

Engineering

- **Absorber / Collector Orientation**

Two (2)-piece design enables selection flexibility

- **Elimination of Air Vent Valve (High Failure Potential)**

Passive Air Bubble Removal Device



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 3 & RITH 4⁺ DESIGNS

<u>Parameter</u>	<u>RITH 3</u>	<u>RITH 4⁺</u>
Sizes:		
absorber	2.85 m² (30.7 ft²)	2.67 m² (28.7 ft²)
glazing	84" x 60" (7 ft x 5 ft)	46" x 96" (4 ft x 8 ft)
'foot print'	~9 ft	~12 ft



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 4⁺ DESIGNS

<u>Parameter</u>	<u>RITH 4⁺</u>	<u>Orient 4</u>
Sizes:		
glazing	46" x 96" (4 ft x 8 ft)	Vertical
'foot print'		~12 ft
glazing	46" x 96" (4 ft x 8 ft)	Horizontal
'foot print'		~ 8 ft



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 4⁺ DESIGNS

<u>Parameter</u>	<u>RITH 4⁺</u>	<u>Orient 4</u>
Sizes:		
glazing	58" x 70" (5 ft x 6 ft)	Vertical
'foot print'		~10 ft
glazing	58" x 70" (5 ft x 6 ft)	Horizontal
'foot print'		~ 9 ft



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 4⁺ DESIGNS

<u>Parameter</u>	<u>RITH 4⁺</u>	<u>Orient 4</u>
Sizes:		
glazing	70" x 70" (6 ft x 6 ft)	
'foot print'		~10 ft



SRP / ELI / Sandia
Solar Domestic Water Heating Project

Minimum Factory Facility Equip Needed (+ labor)

- 1) Foam Injection machine (\$34,675)
- 2) Mold and Assembly station (\$37,800)
 (+\$2K for Horiz Orient)
- 3) Double 45 deg chop saw (\$35,280)
- 4) Fixturing and tooling for extrusions, punch press
 (\$12,600)
- 5) Framewall extrusion die and material
 (\$6300)



Subtotal: \$128,655

SRP / ELI / Sandia
Solar Domestic Water Heating Project

**Minimum Labor and Fees Needed to Install Equip
and Prepare for Certification**

1) Install equipment and setup plant	(\$38,310)
2) Prepare docs SRCC; oversee contracts	(\$37,800)
3) SRCC and FSEC fees	(\$5,000)
4) *Raw materials for 5 RITH	(\$15,000)
<i>Subtotal:</i>	<i>\$95,810</i>

* Supplied by SRP as part of RITH 5-unit order



SRP / ELI / Sandia
Solar Domestic Water Heating Project

Cost Summary for SRCC Certification

1) Equipment	(\$126,655)	<i>+\$2000</i>
2) Labor and fees	(\$95,810)	
<i>Grand totals:</i>	<i>\$222,465</i>	<i>\$224,465</i>



Month (RITH 4)	Thermal Solar Fraction	\$ Savings (\$0.10 kWh)	\$ Solar Fraction
Jan	0.393	\$15.25	
Feb	0.519	\$16.94	
Mar	0.613	\$21.33	
Apr	0.784	\$24.85	
May	0.910	\$26.68	
Jun	1.068	\$23.76	
Jul	1.091	\$23.19	
Aug	1.163	\$21.14	
Sep	1.091	\$21.12	
Oct	0.817	\$21.19	
Nov	0.514	\$16.48	
Dec	0.400	\$14.45	
Annual	0.728	\$246.38	0.703



SRP / ELI / Sandia Solar Domestic Water Heating Project

Conclusions – RITH 4+

Two (2)-Piece Design Enables ‘foot print’
options

80-gallon load > ~0.70 solar fraction

Simplified Air Vent eliminates ALL
moving parts ...

Outline of Manuf Report pending



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH Design and Manuf Update Dec. 10, 2001
in Albuquerque, NM

• **Important Design Issues:**

Engineering

- **Absorber / Collector Orientation**

Two (2)-piece design enables selection flexibility

- **Elimination of Air Vent Valve (High Failure Potential)**

Passive Air Bubble Removal Device



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 3 & RITH 4⁺ DESIGNS

<u>Parameter</u>	<u>RITH 3</u>	<u>RITH 4</u>	<u>RITH 4⁺</u>
Sizes: absorber	2.85 m² (30.7 ft²)	2.67 m² (28.7 ft²)	2.67 m² (28.7 ft²)
glazing	84" x 60" (7 ft x 5 ft)	46" x 96" (4 ft x 8 ft)	46" x 96" (4 ft x 8 ft)
'foot print'	~9 ft	~12 ft	~9 ft



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 4⁺ DESIGNS

<u>Parameter</u>	<u>RITH 4⁺</u>	<u>Orient 4</u>
Sizes:		
glazing	46" x 96" (4 ft x 8 ft)	Vertical
'foot print'		~12 ft
glazing	46" x 96" (4 ft x 8 ft)	Horizontal
'foot print'		~ 8 ft



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 4⁺ DESIGNS

<u>Parameter</u>	<u>RITH 4⁺</u>	<u>Orient 4</u>
Sizes:		
glazing	58" x 70" (5 ft x 6 ft)	Vertical
'foot print'		~10 ft
glazing	58" x 70" (5 ft x 6 ft)	Horizontal
'foot print'		~ 9 ft



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 4⁺ DESIGNS

<u>Parameter</u>	<u>RITH 4⁺</u>	<u>Orient 4</u>
Sizes:		
glazing	70" x 70" (6 ft x 6 ft)	
'foot print'		~10 ft



SRP / ELI / Sandia
Solar Domestic Water Heating Project

Conclusions – RITH 4⁺

Two (2) Piece Design Enables 'foot print'
options

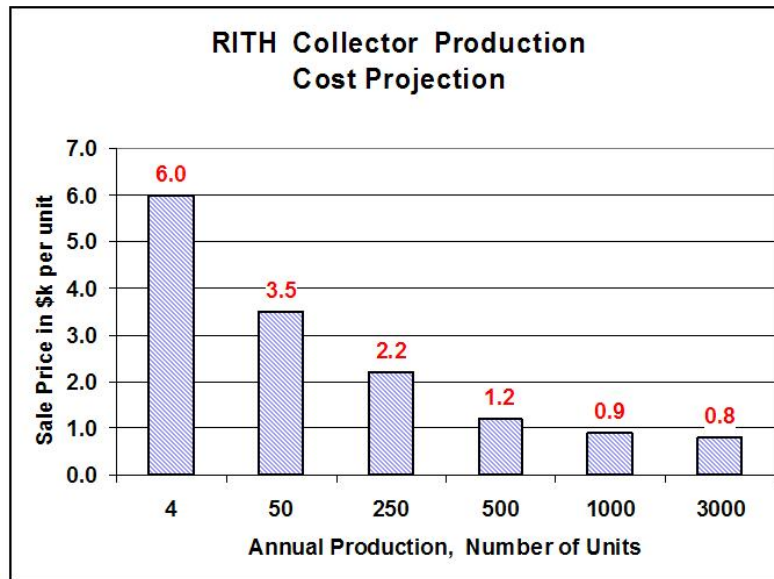
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Simplified Air Vent eliminates ALL
moving parts ...

Outline of Manuf Report pending



SRP / ELI / Sandia
Solar Domestic Water Heating Project



SRP / ELI / Sandia
Solar Domestic Water Heating Project

Minimum Factory Facility Equip Needed (+ labor)

- 1) Foam Injection machine (\$34,675)
- 2) Mold and Assembly station (\$37,800)
(+\$2K for Horiz Orient)
- 3) Double 45 deg chop saw (\$35,280)
- 4) Fixturing and tooling for extrusions, punch press
(\$12,600)
- 5) Framewall extrusion die and material
(\$6300)



Subtotal: \$128,655

SRP / ELI / Sandia
Solar Domestic Water Heating Project

**Minimum Labor and Fees Needed to Install Equip
and Prepare for Certification**

1) Install equipment and setup plant	(\$38,310)
2) Prepare docs SRCC; oversee contracts	(\$37,800)
3) SRCC and FSEC fees	(\$5,000)
4) *Raw materials for 5 RITH	(\$15,000)
<i>Subtotal:</i>	<i>\$95,810</i>

* Supplied by SRP as part of RITH 5-unit order



SRP / ELI / Sandia
Solar Domestic Water Heating Project

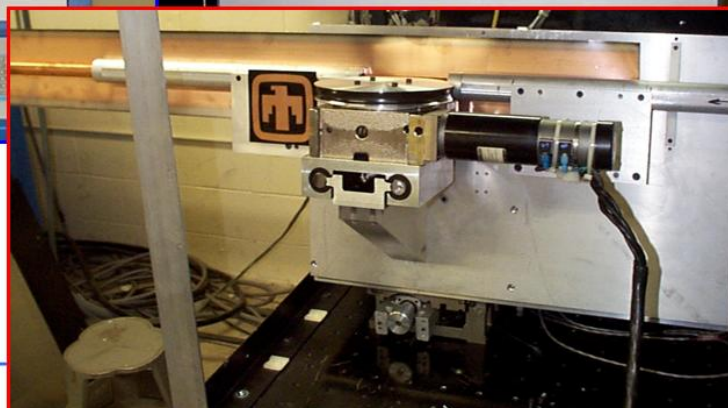
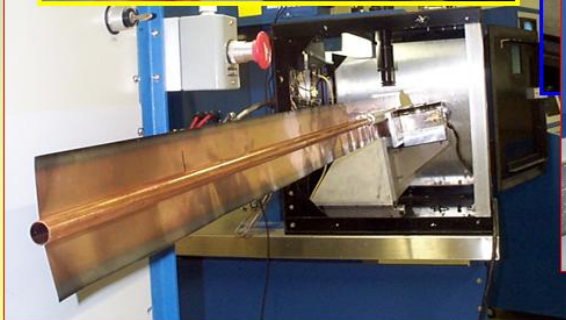
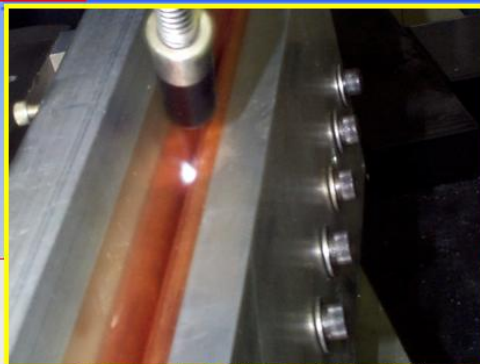
Cost Summary for SRCC Certification

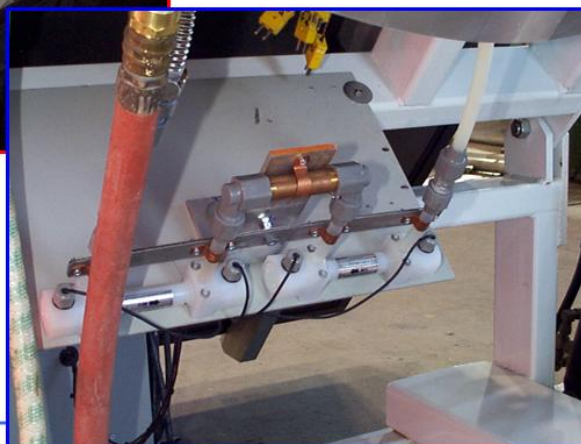
1) Equipment	(\$126,655)	<i>+\$2000</i>
2) Labor and fees	(\$95,810)	
<i>Grand totals:</i>	<i>\$222,465</i>	<i>\$224,465</i>

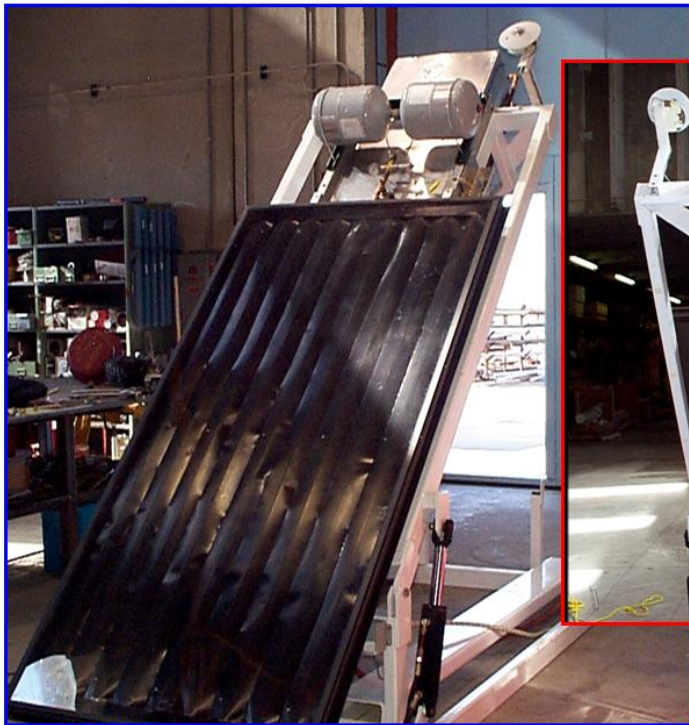




Recent DOE Patented Laser Welding Process to Join Fin / Tubing for Solar Absorbers: Cu/Cu and SS/Cu







Sandia National Laboratories

Month (RITH 4)	Thermal Solar Fraction	\$ Savings (\$0.10 kWh)	\$ Solar Fraction
Jan	0.393	\$15.25	
Feb	0.519	\$16.94	
Mar	0.613	\$21.33	
Apr	0.784	\$24.85	
May	0.910	\$26.68	
Jun	1.068	\$23.76	
Jul	1.091	\$23.19	
Aug	1.163	\$21.14	
Sep	1.091	\$21.12	
Oct	0.817	\$21.19	
Nov	0.514	\$16.48	
Dec	0.400	\$14.45	
Annual	0.728	\$246.38	0.703

Sandia National Laboratories

SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH Design and Manuf Update Feb. 26, 2002
in Jacksonville, FL

- **Discussion Issues:**
 - **SRCC Certification Process**
 - **Manufacturing of Fin-Tube at Sandia**
 - **RITH 6 Testing & Evaluation**



SRP / ELI / Sandia
Solar Domestic Water Heating Project

SRCC Certification Process



SRP / ELI / Sandia
Solar Domestic Water Heating Project
SRCC Certification Process

FSEC (Florida Solar Energy Center) / SRCC visit:
Feb. 25, 2002 with Jim Huggins

SRCC testing fees increased to \$3000 per test

Thermosiphon (and ICS) collectors follow different testing path than active and pool collectors:

Performance testing on roof (including '30 day' stagnation interval; 45-95 days real time)

Heat loss test(s) indoors (for TRNSYS modeling parameters; ~5 days real time)



SRP / ELI / Sandia
Solar Domestic Water Heating Project

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*** Customized wooden rack for RITH (at 4/12 pitch) and on-site support by ELI would probably save 1 - 2 weeks in testing time**

Rack used for both indoor and outdoor tests

Outdoor testing needs 'sides' to simulate limited attic convention (wind) conditions



SRP / ELI / Sandia
Solar Domestic Water Heating Project

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Optimistic total testing completed in 12 weeks...

Position in testing queue determined by physical delivery of unit to FSEC (preparation of paperwork not relevant to queue position)

Other:

Must provide SRCC with Stainless Steel 'Education'

(manuf processes, joint design, corrosion mechanisms, brazing, etc.)



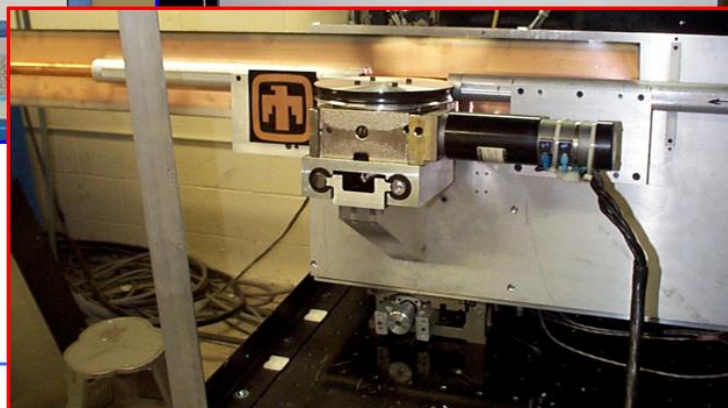
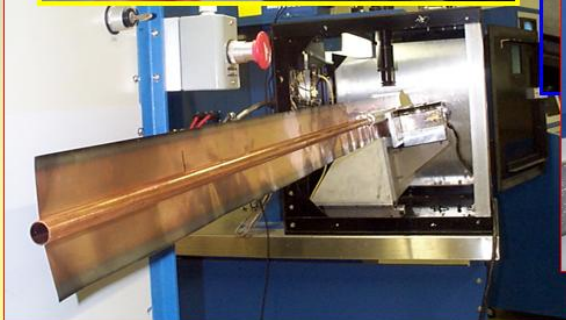
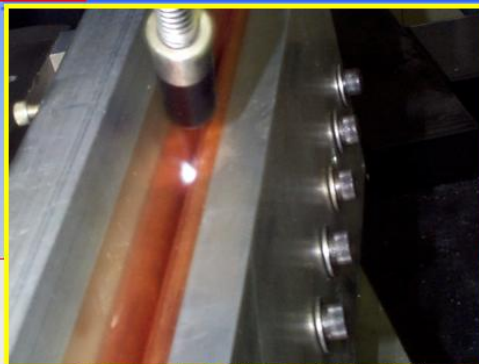
SRP / ELI / Sandia
Solar Domestic Water Heating Project

Manufacturing of Fin-Tube at Sandia





Recent DOE Patented Laser Welding Process to Join Fin / Tubing for Solar Absorbers: Cu/Cu and SS/Cu



SRP / ELI / Sandia
Solar Domestic Water Heating Project

Laser Welding Process:

- **All Stainless Steel tubing ordered and received (parts for ~ 10 collectors)**
- **Selected 316L SS; 5/8" OD (0.585" ID) tubing for risers and 1" OD for manifold for cost and availability**
- **Large volume orders less of an issue for other sizes...
(need to order large volumes for RITH unit cost target... ~20K lb)**



SRP / ELI / Sandia
Solar Domestic Water Heating Project

Laser Welding Process:

- **Power supply and IC repair recently completed**
- **Coil of Black Crystal purchased from ELI (enough for ~ 35 collectors)**
- **Laser Welder fixturing modification to accommodate fin width and SS tubing diameter**



SRP / ELI / Sandia
Solar Domestic Water Heating Project

Laser Welding Process:

- **On schedule to deliver ALL 50 fin-tube risers to ELI by April 1, 2002**

Will ship in lots of 10 when completed...

Other:

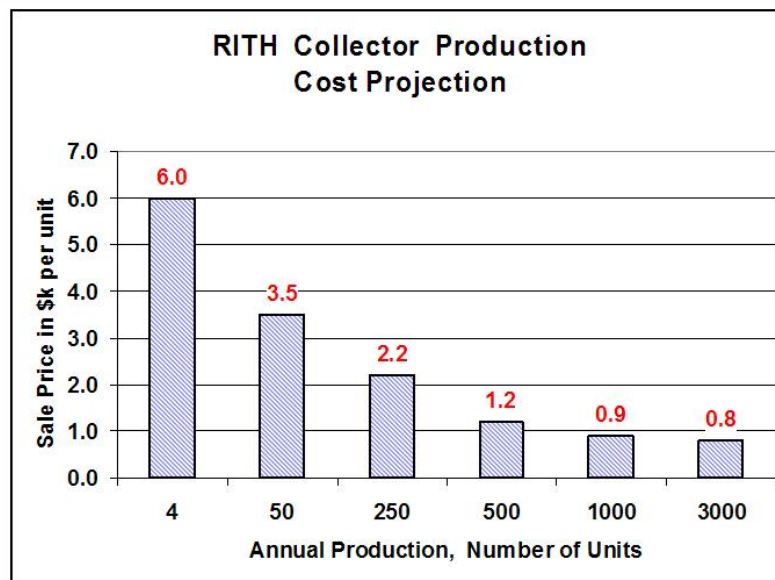
Cu fin/SS tube bond metallurgical analysis

Analysis (metallurgy) of SS tank welds

Analysis (metallurgy) of SS absorber brazing



SRP / ELI / Sandia
Solar Domestic Water Heating Project



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 6 Testing and Evaluation



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 6 T&E

**Installed and Instrumented on Rotating
Platform at the NSTTF**

Two (2) Piece Design
Light weight and Easier Installation
Absorber: Laser Welded Cu Fin/Cu
Tubing; TC instrumented

72-gallon tank: Thermocline TC Tree



Simplified Air Vent with NO moving parts

SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 6 T&E

Testing just beginning (New DAS online)

**Forward flowrates as expected for 4/12
pitch**

Preliminary data:
Flowrate at 6/12 ~2x Flowrate at 4/12
(Tucson Civano installation...)



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 6 T&E

Test plan:

Performance at 4/12, 5/12, 6/12

Nighttime heat loss at 4/12, 5/12, 6/12

**Ground mount for 24-hr operation
with 80 gallon load
(Rotating Platform Trough Activity)**

Replace absorber with Cu/SS



SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH 6 T&E

Test plan:

Performance with Cu/SS Absorber

Summer stagnation...

Document results





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AGENDA (DRAFT)
TECHNOLOGY DEVELOPMENT TEAM MEETING
ELI OFFICES
JACKSONVILLE, FLA
MAY 29, 2002

1. Agenda Review
2. CRADA Tasks Update (Informational)
 - a. (Task 1) Demonstration of Corrosion Tests
 - b. (Task 4) Assess Impact of Co-located Solar Water Heater and PV
3. CRADA Tasks
 - a. (Task 2) Prepare Manufacturing Facility for RITH
 - b. (Task 3) Obtain SRCC Certification
4. SNL-ELI Scope of Work (CRADA Task 3)
 - a. Acquisition of Equipment from Outside Vendors
 - b. Design and Construction of Custom Manufacturing Facility
 - c. Retain Outside Trades for Modifications
 - d. Provide Other Plant Modifications
 - e. Other Reports
5. Unpriced Option – Detailed Process Flow Analysis
Scope of Work: Technical details of each component with respect to materials and fabrication techniques, detailed bill of materials, labor cost information, process flow diagrams, equipment and vendor lists

Discuss the need for this option, cost, schedule, deliverables
6. Sandia Field Studies – Stainless Steel – update
7. Other

GEP 5/14/2002

SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH Design and Performance

Update July 16, 2002

in Albuquerque, NM

• **Discussion Issues:**

- RITH 6 Testing & Evaluation
- SRCC Certification Process



RITH Absorber Performance Metrics; 5/12 pitch; azimuth tracking

Metric	Cu Tubing / Cu Fin	SS Tubing / Cu Fin
Max Fin Temp (C)	Top 113	Top 125
	Mid 85	Mid 100
	Bot 50	Bot 70
Absorber Efficiency (%)	77	78
Thermosiphon Flowrate (L/min)	0.4 to 0.5	0.4 to 0.5
Volume (L) "pumped" per Incident kWh	175L/20kWh = 8.8 L/kWh	168L/18kWh = 9.3 L/kWh
Overall "System" Efficiency (%)	49	43



SRP / ELI / Sandia
Solar Domestic Water Heating Project

SRCC Certification Process



SRP / ELI / Sandia
Solar Domestic Water Heating Project
SRCC Certification Process

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SRP / ELI / Sandia
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SRP / ELI / Sandia
Solar Domestic Water Heating Project

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- **Laser Welder fixturing modification to accommodate fin width and SS tubing diameter**



SRP / ELI / Sandia
Solar Domestic Water Heating Project

Laser Welding Process:

- **On schedule to deliver ALL 60 fin-tube risers to ELI by ...**

Will ship in lots of 10 or more when completed...

Other:

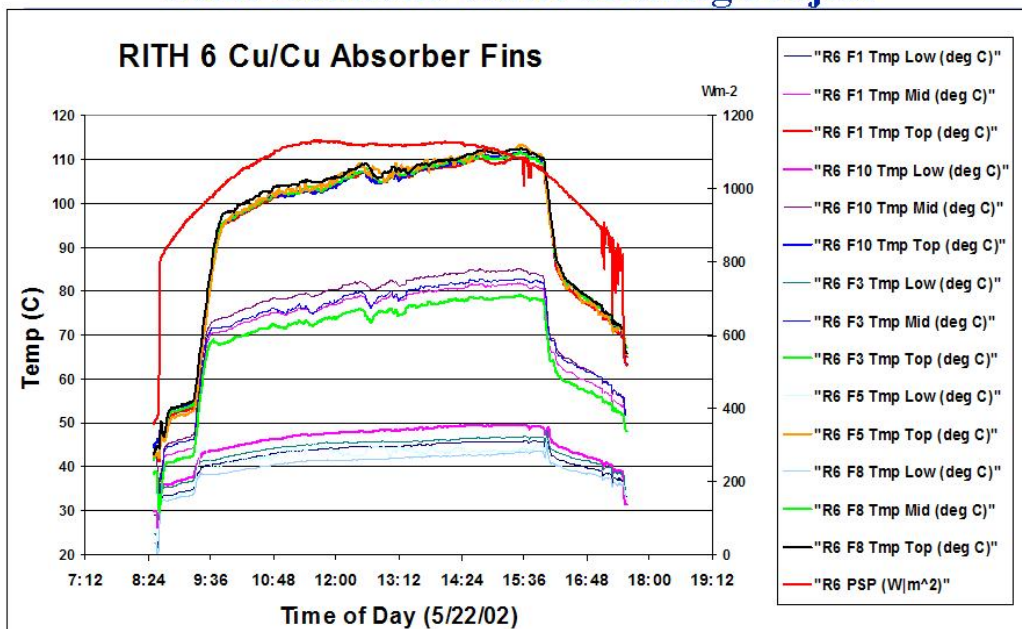
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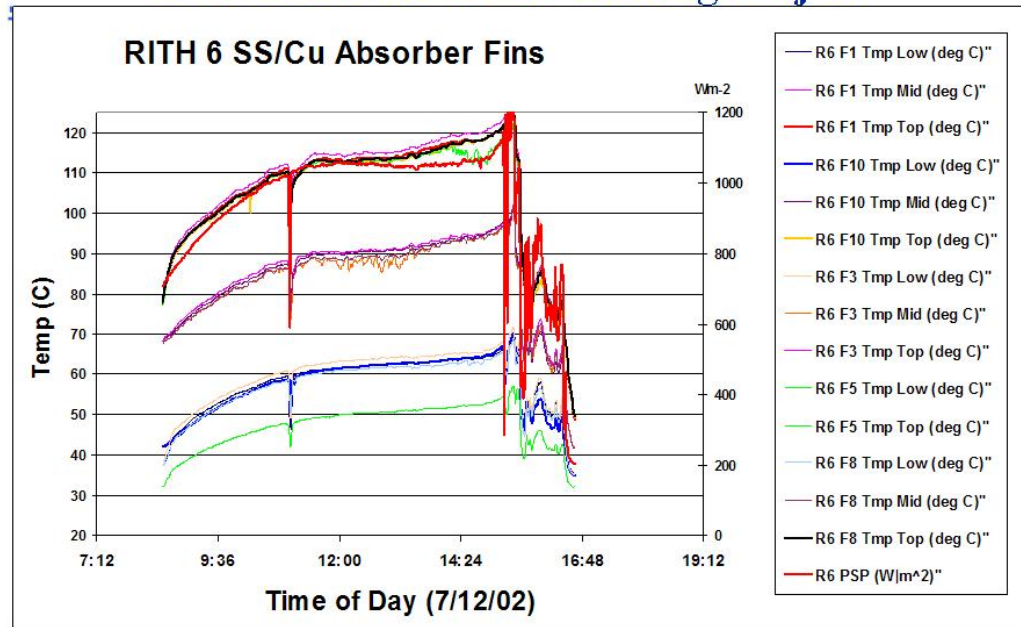
Analysis (metallurgy) of SS absorber brazing



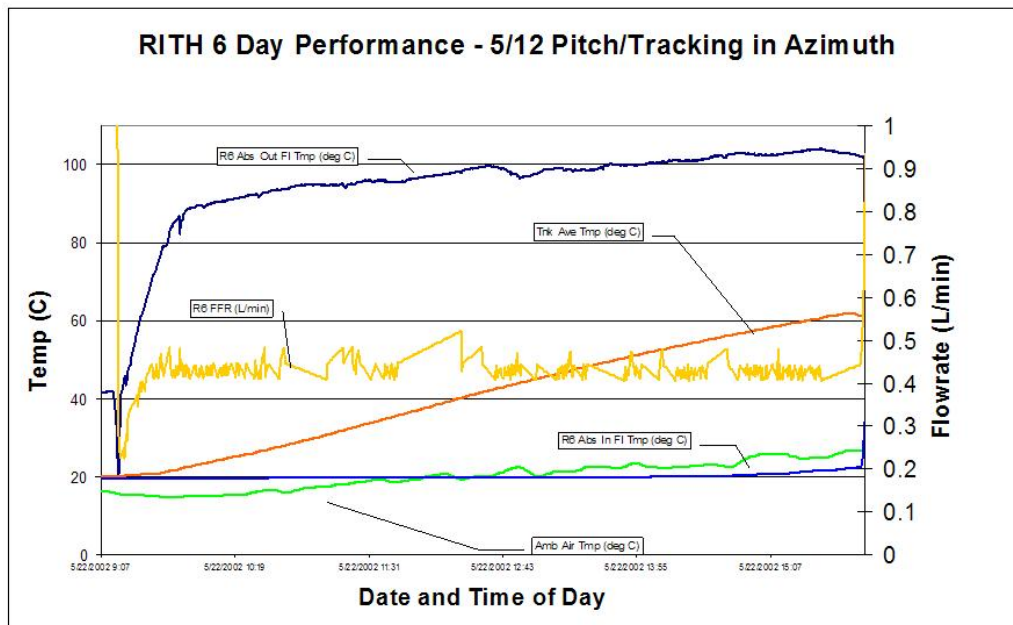
SRP / ELI / Sandia
Solar Domestic Water Heating Project



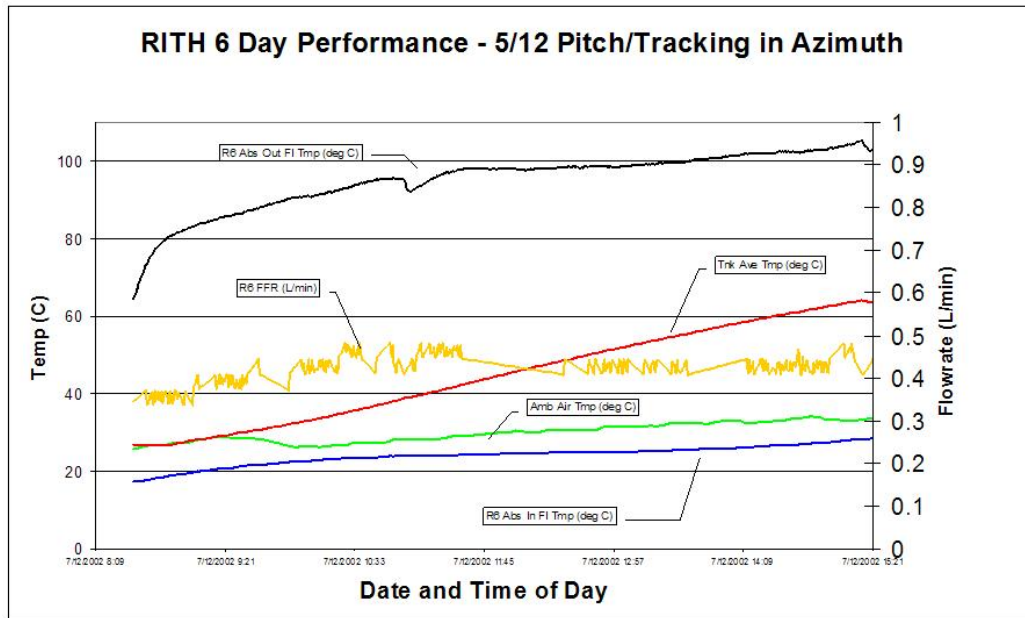
SRP / ELI / Sandia Solar Domestic Water Heating Project



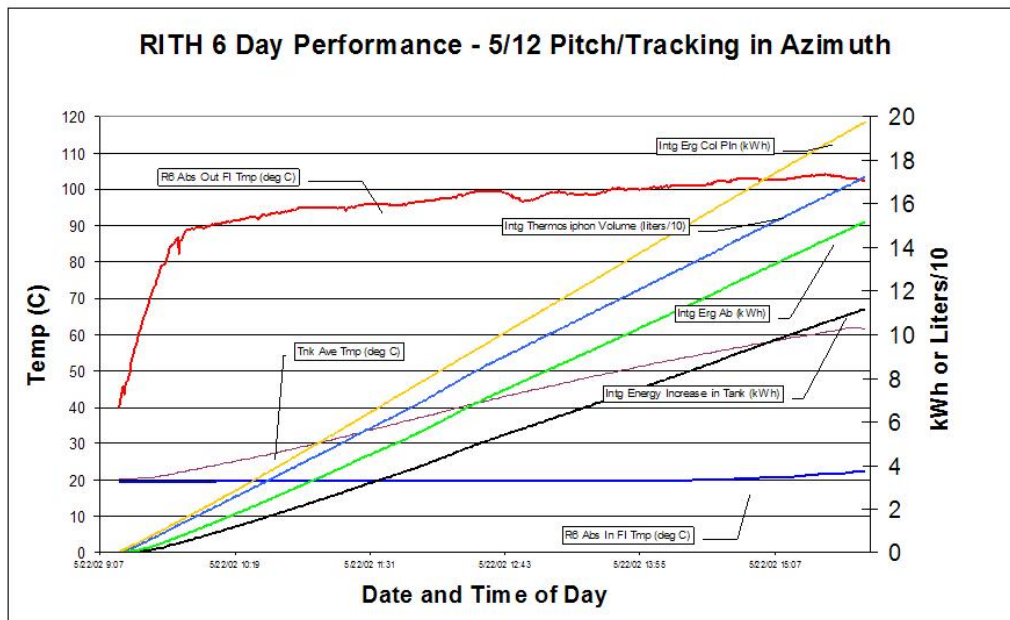
Cu Tubing / Cu Fin Absorber



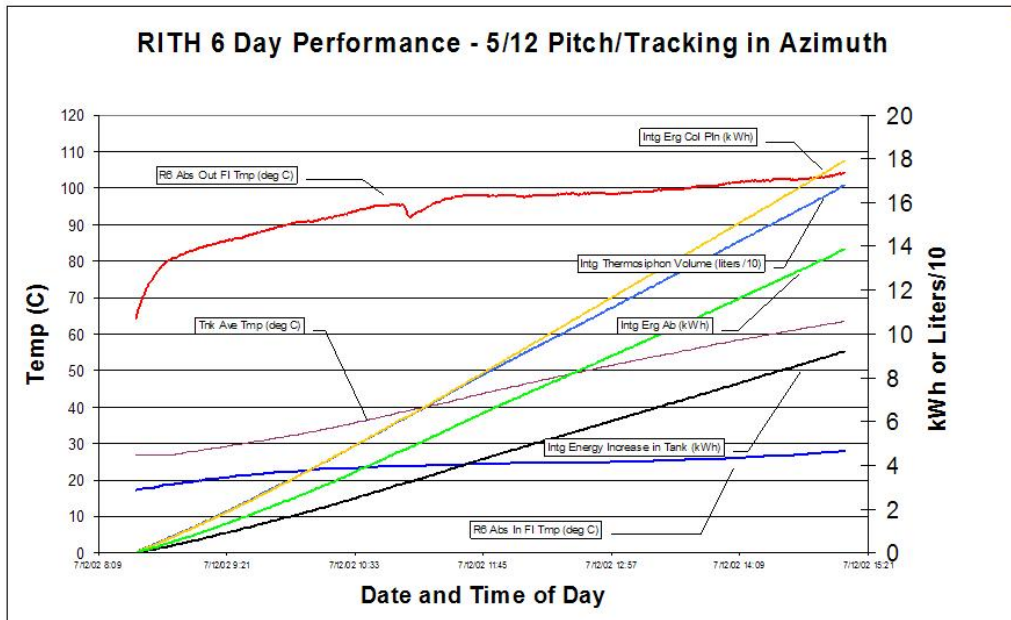
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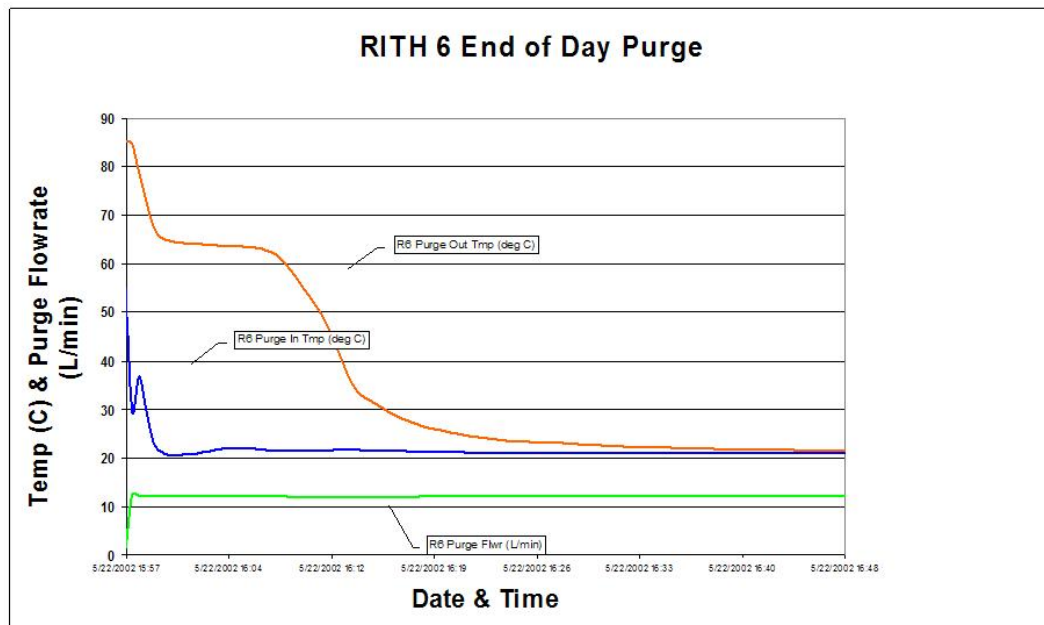
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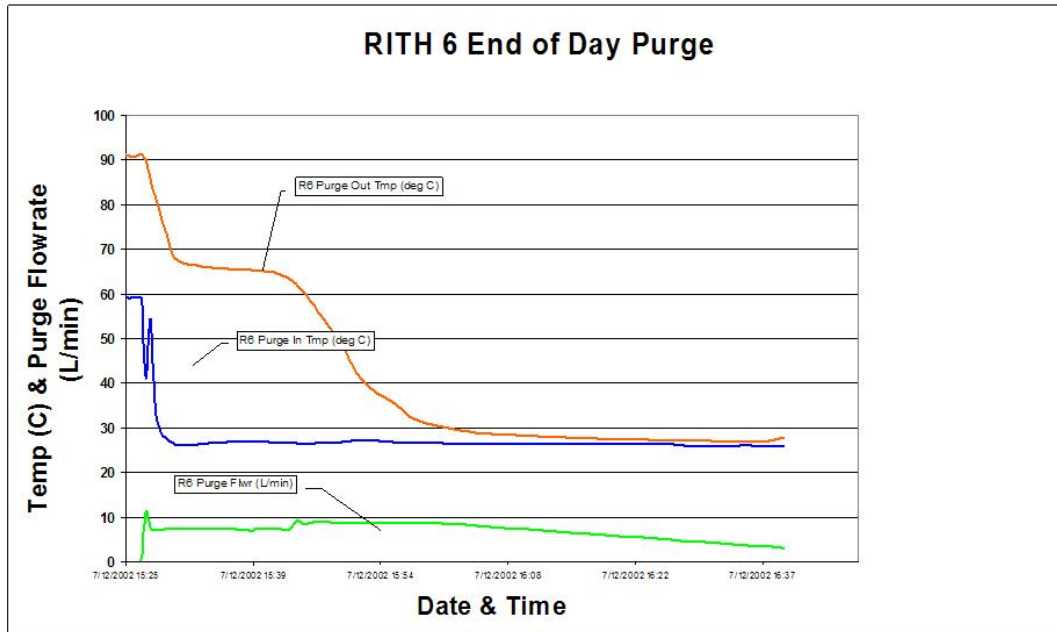
SS Tubing / Cu Fin Absorber



Cu Tubing / Cu Fin Absorber



SS Tubing / Cu Fin Absorber



TDT Meeting Notes

7/15/2002

In attendance: Mike Newman (on speaker phone)

Ernie Palomino – SRP

Dave Menicucci

Rod Mahoney

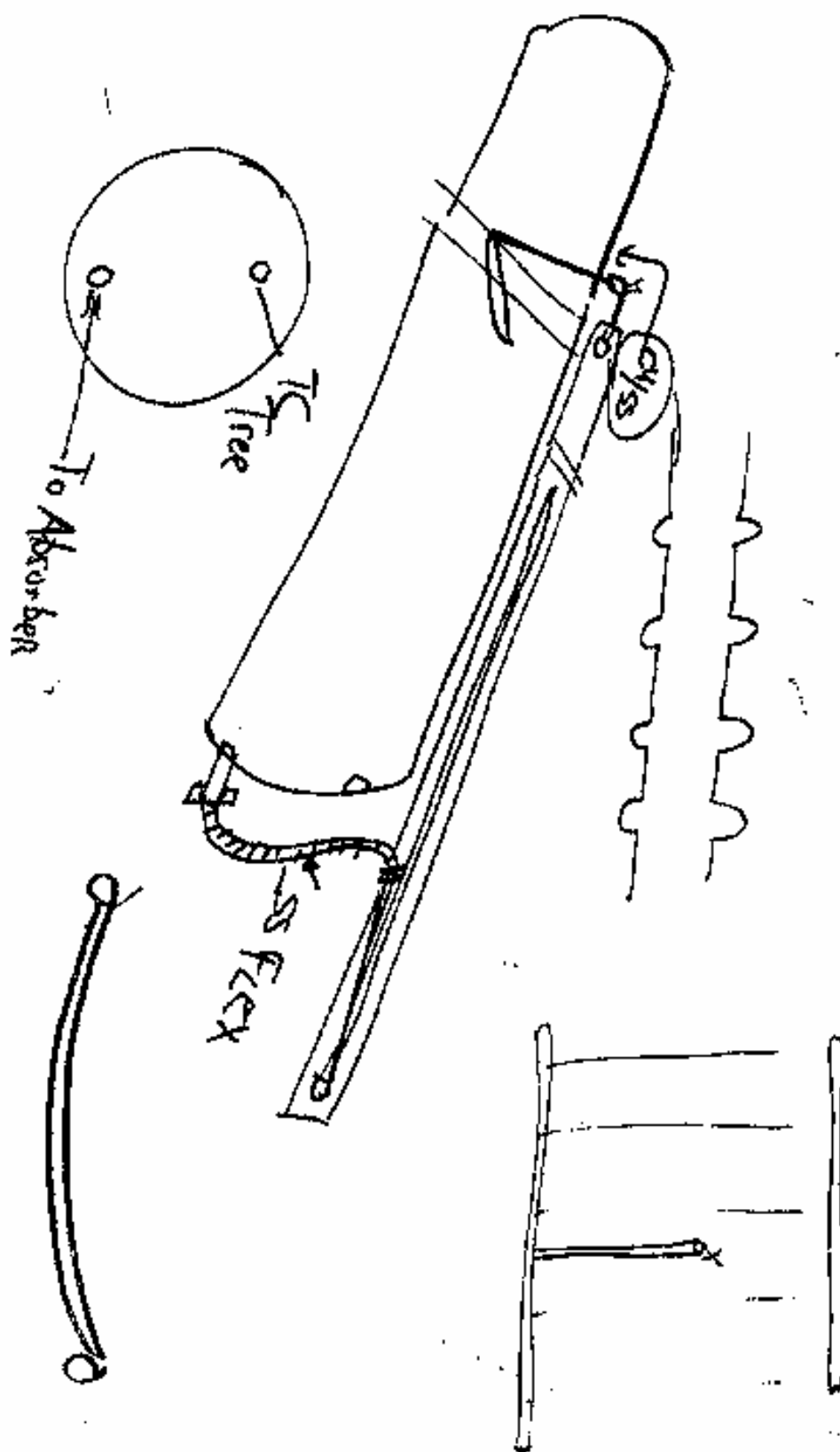
Tim Reynolds

Tim Moss

Chris Cameron

} SNL

Next proposed TDT: Sept. 5 at ELI



Target SRCC certification – January 2003

Priority:

SRCC

ELI:

test rack for RITH unit – additional scope item

testing support – 7/20/02 (SRP)

SNL:

Stainless Steel education for SRCC – additional scope item

Rod Mahoney (POC), Rob Sorensen, Tim Moss to provide analytical and tech transfer support. To do this we need

1) SS samples from ELI – ASAP

2) Cross section analysis of these samples by Rob Sorensen – 8/15/02

ELI – RITH name/designator – proposed Interroof 2000 or Interroof 3270

Production organization

Shear wall design – need to be able to remove glazing while still installed on roof

Site plan and wiring – especially for the SNL laser welder

Finalize manual/documentation

FSU test stand – 5/12 pitch

RITH will be produced by Solar Energy, Inc.

Manufacturing Facility (ELI)

All equipment has been ordered and received

Header fabrication (holes for risers) is hand done, will be automated when sales have risen beyond present capabilities

Corners of housing are being corner notched – this is more expensive but is more consistent

Infrastructure of production floor is complete

Most materials are in except for the box materials

SNL:

Fabricate 60+ fin tubes – Tim Moss 8/1/2002

Complete SS testing of RITH 6 – 7/22/2002, confirm SS vendor options

Tubes to ELI 8/15

RITH fabrication 9/1

SRCC 9/1

SNL-FSEC 10/1

Welder transfer 12/1 (added scope)

Demonstration corrosion test (Cirvano) – (RITH 1/6)

*Prepare manufacturing RITH – in progress, obtain cost and time estimates of packaging, shipping, unpacking, and training of SNL laser to ELI

*Obtain SRCC certification – see list & \$

Assess impact of co-located PV – on hold at SNL

*Develop final report

(* - high priority)

T&E – RITH 4 & 5 $\equiv$ 7/31/2002 stop data collection

RITH 4 – stop data analysis
Remove RITH unit and ship to SNL

RITH 5 – continue data collection – 5/03
Remove and repair roof, or replace with SRCC certified
production unit (builders option)

Future Item $\equiv$ what happens in marketing – who does it?

SRCC- post
Pilot facility $\perp$ 1,000 units/year = ?? = \$1,500
In 2003 (?)

Issues:

ELI facility
ELI staff – David Smith
ELI equipment/infrastructure
SNL welder $\equiv$ IP
SRP equipment – interim agreement
Black crystal – IP

Manufacturing Process Analysis $\equiv$ stainless steel supplier – identify by 9/15/2002

* SRP needs data from SEI to complete report

Business Case Study

* Business Plan/Model

RITH – additional units (6 units to be made)

Tucson Cirvano – Firm
Ft. Huachuca – Firm
Marine – Tuatynino DALNB/Hawaii – Firm
Navy – maybe
JEA/HB - ??
SRCC – a must

Proposed Agenda
SRP CRADA Review Meeting/DER Meeting

January 8 & 9, 2003

DAY One

Date: Wed., Jan. 8

Place: Bldg. 823 (conf room TBD)

Time: 0900

- 1) RITH status report (including conf call with Mike Newman) (Dave, Mike, Rod)
 - a. Manufacturing of 5 units for SRCC (Mike)
 - b. Demonstration system status (Dave)
 - c. SRCC SS issues (Rod)
 - d. Strategy for project completion
 - e. Next visit to ELI plant
 - f. Laser welder (Tim)
 - g. Terminate conf call/RITH status discussion by 1030
- 2) Electric RITH status (Dave)
- 3) Review of status of new funded items (Tim)
- 4) FEMP meeting presentation/SRP reception (Dave, Ernie)
- 5) Lunch
- 6) NREL Solar Hot Water Heating Cost Model (Ernie, Dave)
- 7) Manufacturing Analysis around 1330
 - a. Brief overview of Sandia Capabilities (Gil)
 - b. Review of SRP goals (Ernie)
 - c. Development of plan for completing analysis (all)
 - d. Tour of Advanced Manufacturing Facility
- 8) Adjourn (around 1600)
- 9) Dinner, Gardunos at Winrock, (1830) (Dave, Ernie, others?)

DAY Two

Date: Thurs., Jan. 9

Place: Bldg. 823, Rm. 1503A

Time: 0900

- 1) Review DER strategic planning; input from Ernie (Dave, John Boyes, Ernie, others)
- 2) Meeting at DETL (1045)
 - a. Tour of facility, including new DER equipment
 - b. Brief review (15 minutes) of SRP/PNM microturbine work
 - c. Discussion about fuel cell testing at SRP
- 3) Lunch at CC club with Ernie (1230)
- 4) Adjourn (1330)

SRP CRADA Review Meeting Notes January 8, 2003 at Sandia National Labs

In attendance:

Ernie Palomino (SRP)

Dave Menicucci (SNL)

Rod Mahoney (SNL)

Marlene Brown (SNL)

Tim Moss (SNL)

Gilbert Benavides (SNL)

Mike Newman (ELI) via conference call

Meeting agenda is plain text, *the meeting notes are in italics*

1) RITH status report (including conf call with Mike Newman) (Dave, Mike, Rod)

a. Manufacturing of 5 units for SRCC (Mike)

Original estimate was October 2002; it is now February 2003 to get the first 5 built. There are good reasons for the delay and it will be beneficial in the long run. Single biggest leap (and biggest cause for the delay) for ELI has been the insulating box:

Spent October through December locating new foam and building new table since the old one was too weak and deformed. The reason for this was the foam company was sold to a German company after the foam equipment was bought and the old foam is no longer being manufactured.

Welder broke during welding of new table reinforcements. Parts are on order but have not been delivered. After the welder is repaired it will take about 1-2 days to finish the welding and complete a test to determine if the reinforcements are good enough.

Tank parts are in-house. Mike has a good handle on how to weld the tanks together.

The last endcap will be butt-welded for now but they will continue to look for a better method. Rod suggested putting the weld seam of the cylindrical part of the tank on top. This would keep the inevitable buildup of sediment inside the tank during use away from the weld and potentially reduce corrosion.

Foaming equipment works very well for foaming the tanks.

Drilling the holes in the headers for the risers has been modified. A 5/8-in. hole is now drilled into the header tube and the riser is brazed on. This method leaves no lip whereas T-drilling does. Another solar company uses this method and it works well for them. The braze material used is the one specified by Tim Moss as well as the flux. To T-drill the holes a new machine will have to be purchased at a cost of \$80K. Another machine using a different method, called flow drilling, leaves a collar inside the tube instead of outside the tube as in T-drilling and will cost about \$35K.

All other materials needed to build the first 5 systems are also in-house.

Since the risers are not welded to the headers 304SS can be used instead of 316L.

304SS tubing is potentially more available and cheaper.

SRCC has to pick one out the 5 made. If they decide to pick which one it could take up to 5 days for them to pick one. If a delegated representative is used it will take

about 1-2 for one to be picked. Mike is anticipating the week of February 27th to call SRCC for them to pick one out.

Action Item: Mike will weld a small tank together, including the fittings, and also braze three short riser tubes to a short section of header tube. These will be sent to Tim Moss for Rod to cut samples out for cross sectioning. These are needed to complete the report Rod is writing up as part of the SRCC certification process.

b. Demonstration system status (Dave)

The same week SRCC has picked one for their certification process, three of the other 5 units will be shipped to out as demonstration units. One each will be shipped to 29 Palms, CA, Cervano, AZ, and Ft. Huachuca, AZ. Mike expressed concern that someone from ELI should be present when these systems are installed to make sure it is done correctly.

Installation of these systems will not be scheduled until the systems have been received.

Two out of the three demonstration sites had questions concerning the overflow pan.

The installation specifications supplied by ELI do not mention any overflow pan.

Action Items: Mike will write up the specifications for the overflow pan and send to all parties.

Tim Moss will do a search for manufactured pan. Mike also suggested they could make the pans and ship it along with the rest of the system.

c. SRCC SS issues (Rod)

Rod plans to write up a document, in PowerPoint, and send it to SRCC by mid February. This takes into account receiving and cross-sectioning the samples from Mike, and Rod's limited time for this project.

d. Strategy for project completion

Critical deliverables:

- 1) 5 units built
- 2) SS information to SRCC, test schedule
- 3) 3 units shipped to demonstration sites, Cervano will be first
- 4) Laser welder installed and incorporated into facility
- 5) Business model (type and depth TBD)
- 6) Manufacturing analysis

e. Next visit to ELI plant

A TDT meeting is proposed in early March. Another site visit in early April is proposed for Ernie and his boss to tour the manufacturing facility. During this trip Ernie also plans to visit SRCC so Ernie's boss can get an idea of what is involved in testing to obtain SRCC certification.

f. Laser welder (Tim)

Laser system has been disassembled and the contractor has the boxes made. It is ready for shipping after ELI has made the first 5 units. It will take about 1 week to box the laser system and ship it to ELI.

g. Terminate conf call/RITH status discussion by 1030

2) Electric RITH status (Dave)

Very little has been done since this was put on hold in order to concentrate on getting the first 5 units made for SRCC certification.

3) *Review of status of new funded items (Tim)*

Houser has a new contract for RITH 5 data collection. He is still the only one able to download the data from RITH 5.

The transformer for the laser system has been sent to ELI.

The laser system is ready for shipping to ELI but is on hold until the first 5 units are made for SRCC certification.

The report and presentation of RITH 5 testing at a national conference TBD. It was suggested to present this report at the FEMP meeting in August 2003 in Orlando, FL. Rod suggested also presenting the Sol-Gel coating and the SS corrosion issues also at this meeting.

Rod will put together a PowerPoint presentation concerning the SS corrosion issues and send this to SRCC as part of the certification process for the units. It is planned that a trip by Rod to SRCC will be avoided by sending them the PowerPoint file.

The co-location study needs to get restarted. This was put on hold also to concentrate on getting the first 5 units made for certification.

4) *FEMP meeting presentation/SRP reception (Dave, Ernie)*

Action item: *Dave is to get cost information for this meeting to Ernie.*

5) *Lunch*

Good

6) *NREL Solar Hot Water Heating Cost Model (Ernie, Dave)*

7) *Manufacturing Analysis around 1330*

a. *Brief overview of Sandia Capabilities (Gil)*

b. *Review of SRP goals (Ernie)*

c. *Development of plan for completing analysis (all)*

There are two fears driving the need for this:

1-Can ELI manufacture 3,000 units a year with the current layout and process flow?

2-Can they make the cost objective of \$1,500 per unit installed cost?

A question to be answered is the quality process control. Is it defined and does it work?

The proposal is to do a process validation cost study to address the two fears and the one question. Ernie would like this to be completed about mid May.

Action Item: *Tim Moss will write a proposal to send to Gilbert Benavides for his review and from this determine if his schedule allows him to do this work.*

d. *Tour of Advanced Manufacturing Facility*

Cancelled and replaced with a trip to the solar site to look at several RITH systems there.

8) *Adjourn (around 1600)*

9) *Dinner, Gardunos at Winrock (1830) (Dave, Ernie, others?)*

SRP / ELI / Sandia
Solar Domestic Water Heating Project

RITH SS Corrosion

Update Jan. 08, 2003
in Albuquerque, NM

• **Discussion Issues:**

- **SS Corrosion Overview Strategy**
- **Corrosion Fundamentals**
- **Mitigate corrosion potential by:**
materials selection, joint design, manuf
processes; welding, brazing (water potable)



SRP / ELI / Sandia
Solar Domestic Water Heating Project

SS Corrosion Overview Strategy

- **Deliver document (in PowerPoint format) to SRCC**
for review by mid-to-late Feb. 2003
- **SS corrosion mechanisms overview**
Examples of each mechanism with viewgraphs
and literature references
- **How does RITH 'design' address and mitigate each**
potential corrosion mechanism area?



SRP / ELI / Sandia
Solar Domestic Water Heating Project

SS Corrosion Mechanisms & Mitigation

- **Crevice corrosion (oxidation...)**
 - **joint design and joining processes must eliminate ALL crevices**
 - **both brazing and welding process relevant**

- **Grain boundary selectivity (carbides)**
 - **only welding process relevant**
 - **carbides formed at grain boundary upon re-solidification**
 - **material selection – low carbon content (316L) important**



SRP / ELI / Sandia
Solar Domestic Water Heating Project

SS Corrosion Mechanisms & Mitigation

- **Water Potability and other issues**
 - **brazed joints in absorber**
 - selection of ‘potable certified’ brazing alloy**
 - appropriate clean method(s) of brazing flux**
 - **304 SS alloy acceptable (<\$?) for absorber (not welded...)**

- **Stress corrosion cracking**
 - **higher service temperature (than RITH) concern...**



SRP / ELI / Sandia
Solar Domestic Water Heating Project

SS Corrosion Mechanisms & Mitigation

- **Chloride**
 - literature references
 - grain boundary selective...
 - Cl concentration, Temp, and SS material dependence...

- **Galvanic Couple (dissimilar metals) at Fin/Tube**
 - Cu fin/SS tube
 - must have electrolyte (i.e., water) present for corrosion to occur
 - minor issue: absorber temperatures high ($>70^{\circ}\text{C}$);
diurnal cycling of absorber; backside of fin only; Fe...



SRP / ELI / Sandia
Solar Domestic Water Heating Project

SS Corrosion Overview Gating Items

- **Need samples for cross-sectional analysis**
minimum of 2-3 weeks for preparation...

- * **Tank: seam and endcap welded joints**

- * **Absorber: riser to manifold brazed joints**

Cu fin/SS tubing completed



SRP / ELI / Sandia
Solar Domestic Water Heating Project

SS Corrosion Summary

- **Brief description of SS Corrosion Overview**
- **Document preparation can be done in parallel with sample section analysis work**
- **Estimated completion: mid-to-late Feb. 2003**



Meeting Minutes: SRP RITH Meeting 8/18/03

Attendees: Ernie Palomino, SRP; Dave Menicucci and Tim Moss, Sandia National Laboratories; Mike Newman, ELI; David Smith, Dave Strathmann, and Phil Burdette, SEI.

SRP stated that ELI faces several hurdles in selling RITH commercially (to Pulte), including having a certified product, a demonstrated manufacturing facility, a Table of Organization, the ability to satisfy markets, and marketing capabilities.

Pulte homes needs to buy solar hot water or continue contesting the law requiring solar hot water in homes in the courts. They may have options with SolarGenix, ELI/SEI, and Unisolar (using PV in Tucson). Pulte is looking for a long-term solution, not a quick fix. A solution must satisfy homebuilding requirements. Timing is KEY; Pulte is very interested. Pulte needs 20 units per week beginning around January to March 2004, for a total of 1,300 homes in Civano, AZ.

☐ Pulte wants to visit our manufacturing plant to assure themselves we are capable and viable.

☐ Pulte wants independent testing/verification by Building Science (Boston), Armand Rudd.

☐ Alan Kennedy, Reg. VP, Pulte Homes AZ, agreed to pick a house to install the system right away (REVISED TO Sept 18th or 25th).

Alan asked if a western exposure would work, and Sandia said, "Sure, you only lose 15% to 25% of the effectiveness of the system when it is west facing. South is ideal, but Alan said while most homes are facing North/South, some are not. South is optimal, but SE or SW will result in 5% loss."

Alan Kennedy asked questions about what stage of completion the home should be at to install our system.

☐ Alan needs to get special trussing installed to support the 800-pound load.

☐ Alan needs to get the engineering for that.

☐ Roof sheathing and felt should be installed before our install.

☐ Plumbing stubs should be installed, possibly a ¾" supply line, insulated back.

☐ Need a drain line for the drip pan.

☐ We need to create an installation checklist for Pulte to be sure they give us homes to install at the right stage, and to know what we need when we show up.

To sell Pulte, we need to build their confidence level. Show an installation and show how it works. Prove it is the right move for a large commitment. We must allow the trades to observe the installation for training purposes. Alan Kennedy said he will arrange for metering of the RITH unit by Armand Rudd of Building Science, Boston. Dave Menicucci offered SNL support for testing and metering.

☐ We should contact Armand Rudd of Building Science, Boston, to discuss testing, metering, etc., for results. We need to be sure he knows how to meter for positive results.

- ☐ ELI must develop a solid stainless steel (SS) or HDPE, UV stable plastic, unit for severe corrosive, high-salt environments and provide additional pricing for optional version/model.
- ☐ Mike committed to a non-corrosive, high-salt unit (SS/HDPE) for delivery in December 2003 for Navy.
- ☐ Dave M. already told them we have a unit, he must communicate we DO NOT. He said this will be a very important test.
- ☐ Since certification should be completed before December 2003, and there is a risk that we will get stuck with bad numbers, Dave M. suggested we verify that the unit will thermosiphon before numbers are finalized. Mike agreed to follow up with FSEC. (There was a sharp bend in tubing that changed the thermosiphon ability: re: Tim.)
- ☐ Verify all S/S fasteners are 316 grade, not 400 or other.

ELI needs to acquire black crystal fin and has two options:

- ☐ Construct a production line to manufacture it ourselves. ☐ Timing ☐ Cost?
- ☐ Work with AET.

Either one, Sandia will assist. Sandia assured this will not affect other issues with ELI, like licensing, or give AET a license.

LAB PHOTOS: from Sandia

- ☐ Better housecleaning, deburring the drilled pipes before brazing will result in a better joint. Suggest we ream out the drilled edges of metal before brazing.
- ☐ Use of a detergent cleaner to remove oils before brazing will improve quality of welds and longevity of system (not alcohol, but a detergent).

All lab welds tested very good; all will perform as planned or expected. A new technique is recommended for the collector return fitting in order to ensure no possibility of crevice corrosion.

As we gain experience in welding, the quality will improve.

REMARKETING – QUALITY ASSURANCE ... We may quote Sandia National Laboratories as saying “Sandia National Laboratories conducted rigorous testing and did a cross section analysis of all brazed and welded parts of both tank and collector; first, to insure structural integrity of the unit and second, to insure there are no potential sites for corrosion, which could cause system failure.”

- ☐ We need diagrams of the unit to help everyone (Pulte, installers, trades) understand what they are, how big they are, how to handle them, how to install them, service them, repair them. Mention that the system was designed to make it easy for plumbers to access the fittings in the attic.
- ☐ Dave M. suggested we might be able to eliminate one or two Swagelok (expensive) fittings by extending the tube from the collector to be long enough to reach the tank.
- ☐ A benefit of our design is that “No brazing or field welding” is required to make installation easier.

- ☐ Verify that the small, 1/8" diameter Teflon line used for the air eliminator will not "lime up" or clog. Should we increase the diameter of this tube to reduce risk of liming?
- ☐ Tim Moss will research 1/8" Teflon re: liming

Dave M. requested Tim process the necessary paperwork to extend the loan of the laser welder and any other equipment loaned under the CRADA to ELI, for the maximum length of time. This is necessary to support the investment in manufacturing as well as marketing and sales.

SNL wants the RITH to be successful and does not want any return other than the recognition.

Calex Homes, Craig Curtis, from Phoenix, AZ, and Southern California expressed an interest in:

- A. A potential buyer of our systems
 - B. A potential investor in another manufacturing facility out west?
- Some competitors of ELI want to build this RITH unit.

- ☐ Once we are on board with Pulte, meet with Craig Curtis of Calex.

Gold Canyon, model home, older RITH unit with copper, is to be removed at the request of the homeowner. This was approved by Ernie Palomino of SRP. Do not know why, just requested. Unit to be shipped to Sandia for disposal. We have no interest in it. Note: apparently Craig Curtis would like it, and it's OK with ELI if SRP wants to donate it to him.

- ☐ The air eliminator needs to have the 1/2" to 1/4" reducer either redesigned (use an SS disk or washer to braze tube to connector) or sourced for SS.

What Ernie and SRP want:

1. Demonstrate that RITH is successful.
2. Show that it can happen.
3. Define our relationship, where RITH fits into our vision.

Ernie asked:

What happens after the installation?

What infrastructure will you provide to repair/replace units in the future?

SRP will facilitate the introduction of RITH product. We may not use their name, though, in advertising.

SRP will hire an outside consultant to evaluate renewable energy. Where is sustainable energy? Incentivized sources have limited lifetimes. RITH may have value as a demand management tool. Five years ago, SRP was under different management; they were joint venture oriented. Today, SRP management is more bottom-line oriented. The question is: How do we create a mutually beneficial business relationship?

- ☐ We need to figure out what it takes to make our business sustainable.

There are 25,000 to 30,000 homes being built in Arizona.

Yes, we are interested in reducing PEAK DEMAND.

Rate of return? Do we care? I can't answer that.

Ernie will investigate how SRP will extend the loan period of the auto brake to the maximum number of years, and for how long.

ELI and SEI should review market opportunities in AZ, but also ☐Nevada (passing portfolio standards), ☐New Mexico, and ☐California (looking at renewable energy portfolio standards).

ELI should focus on demonstrating a live customer on a real sustainable business venture. Note: The Ft. Huachuca contractor bid **\$5000** to install the RITH unit.

☐ ELI needs to get Sandia's study of the FULL LIST of all tax rebates and incentives. It is the only complete listing in the USA. Dave M. and/or Tim will provide it to ELI.

Ernie Palomino, SRP, on what we need to do to get a good reception at SRP:

1. Get a unit installed at Pulte, and Pulte on board with RITH (committed).
2. Alan Kennedy, Pulte, learn his plans, criteria, etc?
3. Alan Kennedy, Pulte, visit ELI.
4. SRP manager also to visit ELI.
5. Provide a Pulte presentation (Pulte is big in Phoenix, San Diego, and Los Angeles) with an installed price so that they can make a standard that comes in every one of 1,300 homes in Civano. Show what his commitment saves, as in NO marketing costs for SEI/ELI to sell to Pulte.
6. Identify and title to key equipment, and solve sourcing of black crystal.
7. Given cost factors, present several business case opportunities: Which options make sense to SRP? Show how we can achieve sustainable business without subsidy. Green tags may factor in? How do you certify them; a problem? SRP is not interested in the green tags especially if we think they will be helpful to ELI.
8. Warranty and support services must be provided. Recommend AGAINST hiring a local salesperson in Phoenix; not needed for Pulte. Define how you would handle callbacks in customer homes that are installed.
9. Royalty? Ernie expressed that SRP will defer payment of any royalty on the first 1,300 to 1,500 "experimental" units to be sold to Pulte or others. Later, will determine royalty arrangements if any.

Appendix E.

Pictures of Diffusers



Figure E-1. Early RITH diffuser used in RITH 80 system.



Figure E-2. Alternate view of RITH 80 diffuser.



Figure E-3. RITH 3 diffuser.



Figure E-4. RITH 3 diffuser.

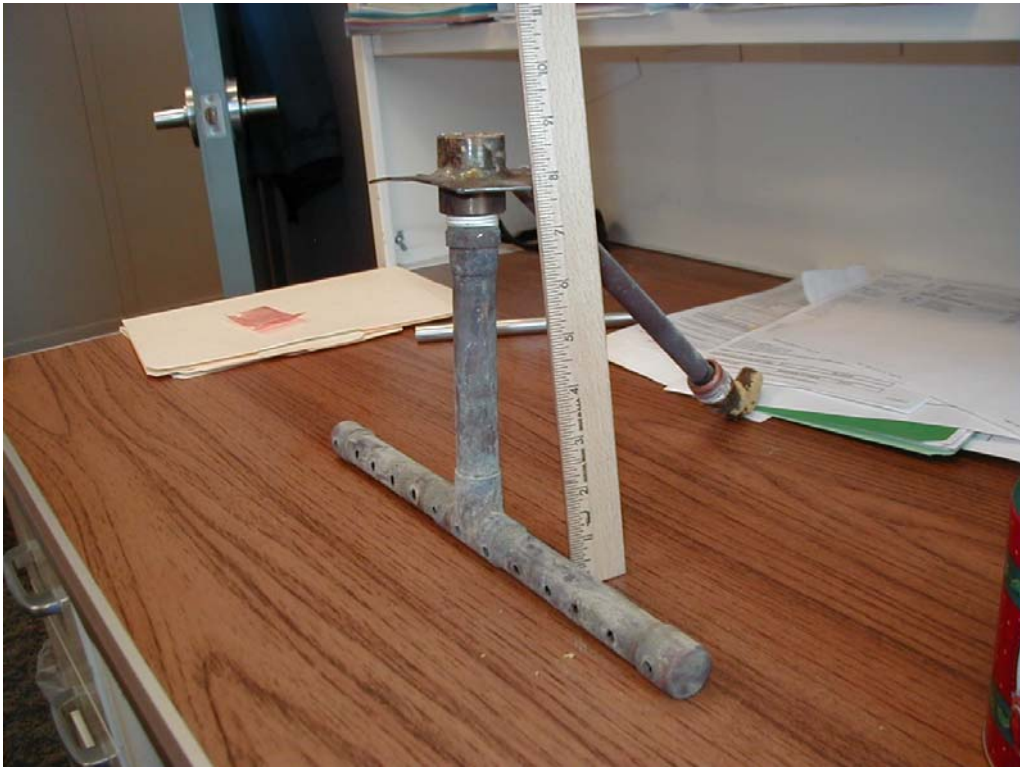


Figure E-5. RITH 6 diffuser.



Figure E-5. RITH 6 diffuser.



Figure E-5. RITH 6 stainless steel diffuser.

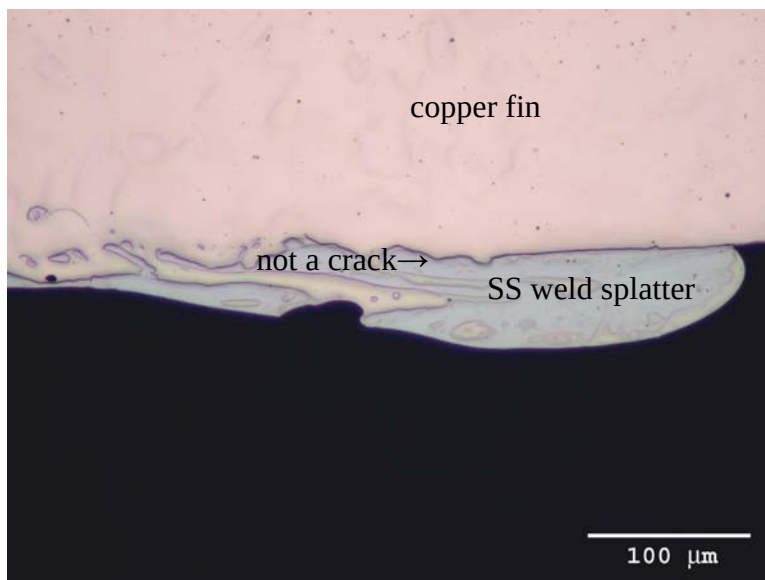
Appendix F.
Laser and Thermal Analysis of
Welding Stainless Steel Tube to Copper Fin

Sandia National Laboratories

Albuquerque, New Mexico 87185-5800

date: April 30, 2002
to: D. F. Menicucci, Dept. 6219 MS 0753
from: T.A. Moss, Dept. 6216 MS 0703
subject: Cross section analysis of laser welding a copper (Cu) fin to a Stainless Steel (SS) tube

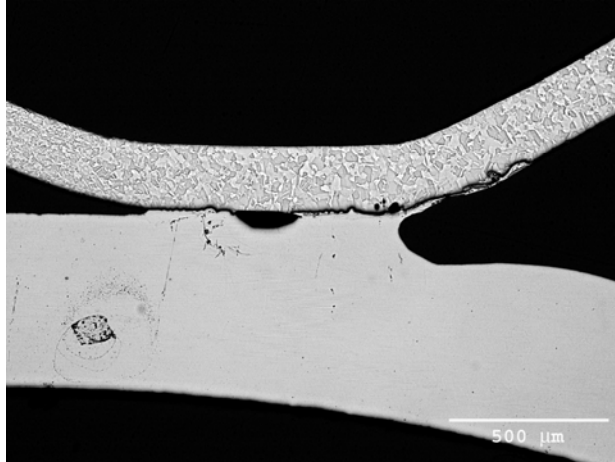
Fred Hooper and Bo Bridges laser weld a 0.008" copper fin to 5/8" OD 316L SS 0.20" wall SS tube using a process developed by Rod Mahoney and Phil Fuerschbach. Fred and Bo, working with Rod and Phil, welded the copper fin to SS tube using four different weld parameters in order to determine the optimum welding parameters. Three samples from each weld sample were cut out for cross-sectioning, particularly looking for cracks and porosity in the weld area. The cross-sectioning showed all the welds looked very good. One set of weld parameters was not superior to the others. Each had very little porosity and cracking and the contact, or weld, length between the copper fin and the SS tube was fairly consistent, about 0.4 mm, which is about twice as thick as the copper fin (0.2 mm). The following pages show the results of the cross sectioning for each weld parameter used as well as the weld length (L). In all the pictures the copper fin is on top and the SS tube is on the bottom. The copper is bent more than the tube because it was bent out of the way for a visual inspection before cross-sectioning. Note these pictures show the copper fin is not being thinned from the welding. All the pictures also seem to show a crack along the copper/SS interface. This is an optical illusion caused by the different polishing rates for the two dissimilar metals. The copper is removed faster than the SS so it is vertically lower. Because of the step depth change between the copper and SS and the microscope's lack of depth of field, one side is slightly out of focus, making it appear like a crack. The cross-sectioning was done rapidly so the samples were not as polished as they could be and the etching – which is tricky to begin with, let alone etching dissimilar metals such as copper and SS – was also not as good as it could be. It was deemed more important to get results quickly since time was very important.



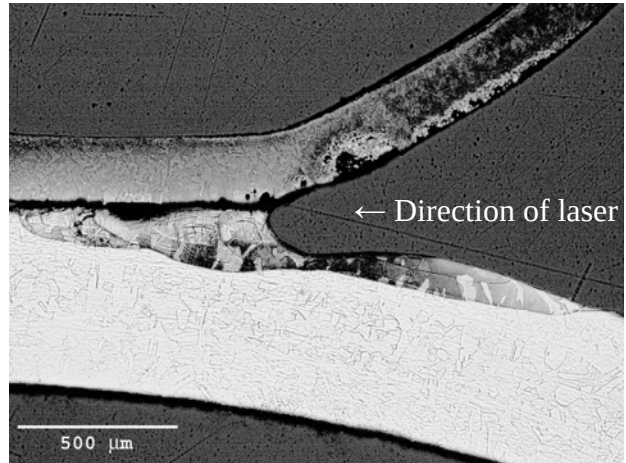
This is a closeup of weld sample A3 showing the weld splatter from the SS. Note the appearance of the crack between the SS and the copper. This is not a crack but just the difference of removal rate of copper vs. SS during polishing and lack of depth of field of the microscope.

Weld Sample A

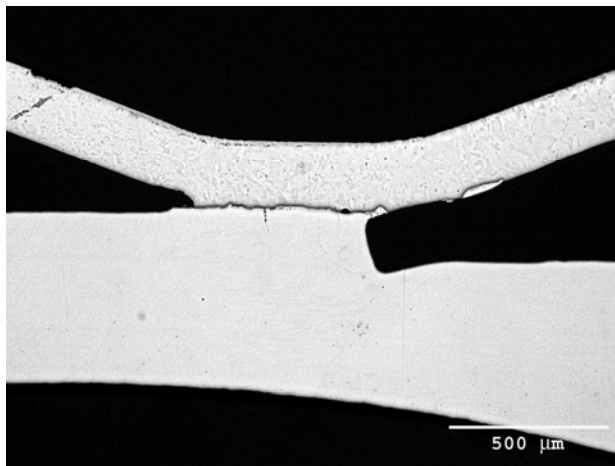
Power: 1.4 Joules; speed of tube through laser welding: 51 in./min; 140 pps (pulses/sec); 0.0061" spacing between weld centers



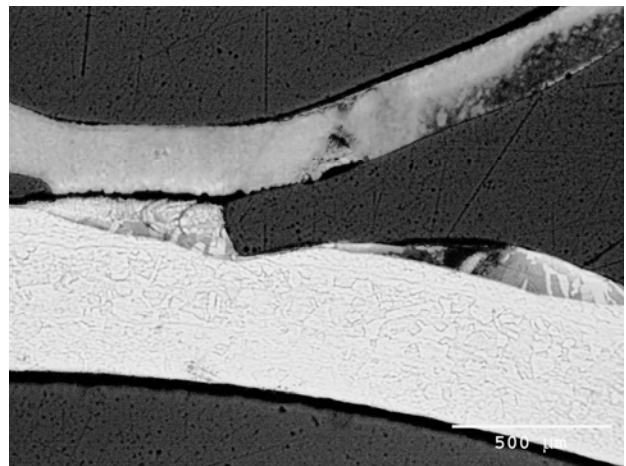
Sample A1- as polished L=0.59 mm



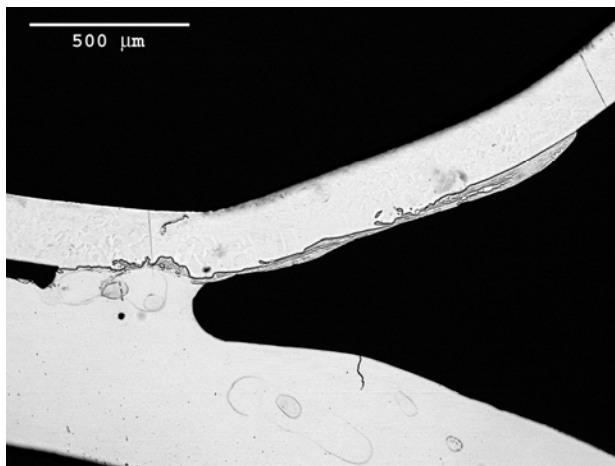
Sample A1- as polished and etched



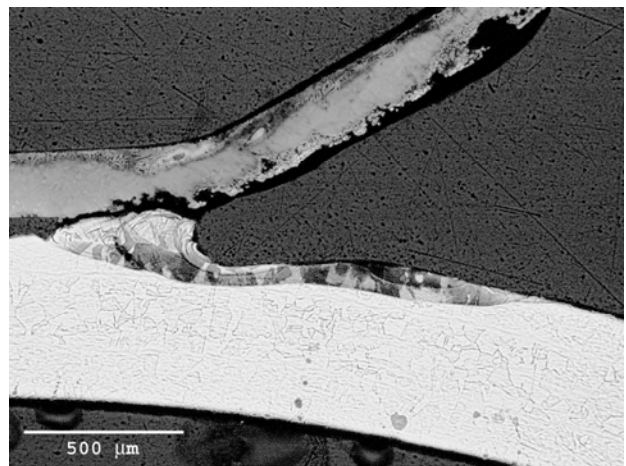
Sample A2- as polished L=0.56 mm



Sample A2- as polished and etched



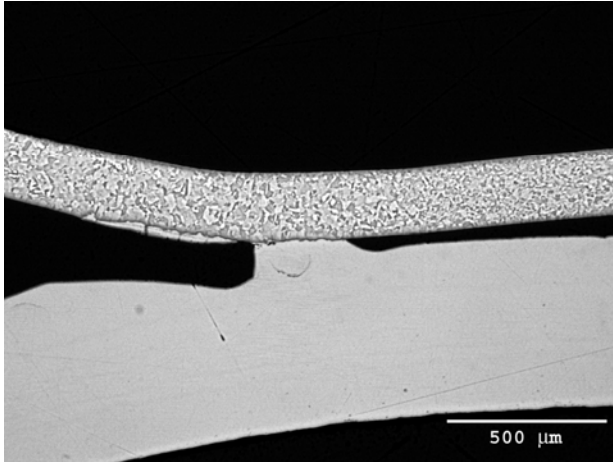
Sample A3- as polished L=0.46 mm



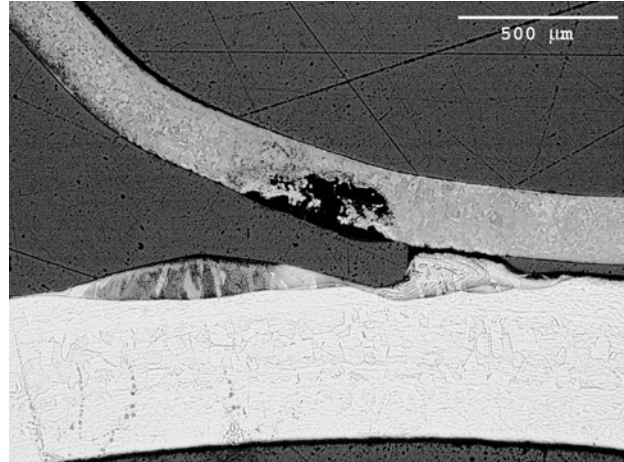
Sample A3- as polished and etched

Weld Sample B

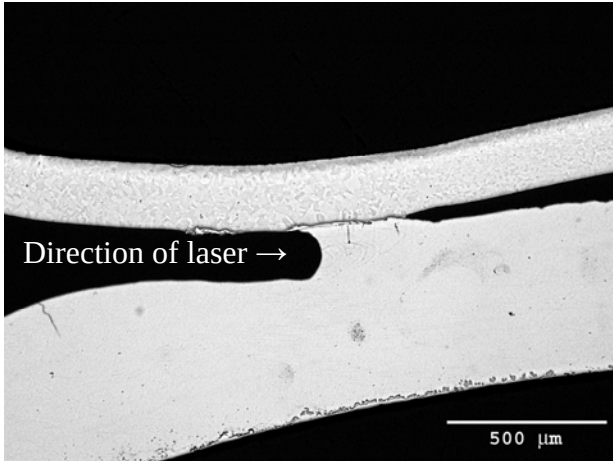
Power: 1.4 Joules; tube speed: 67 in./min; 140 pps; 0.008" spacing



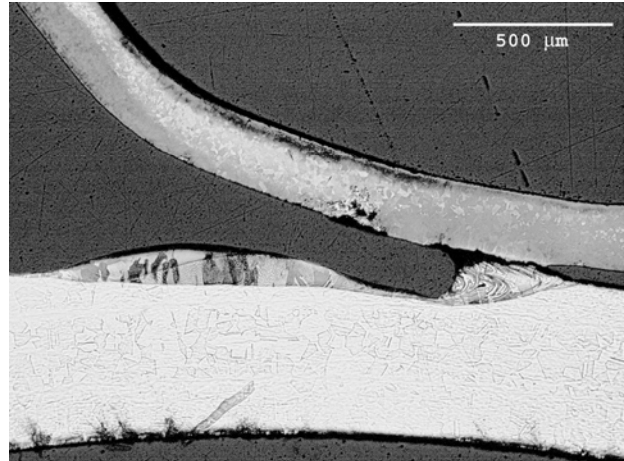
Sample B1- as polished L=0.30 mm



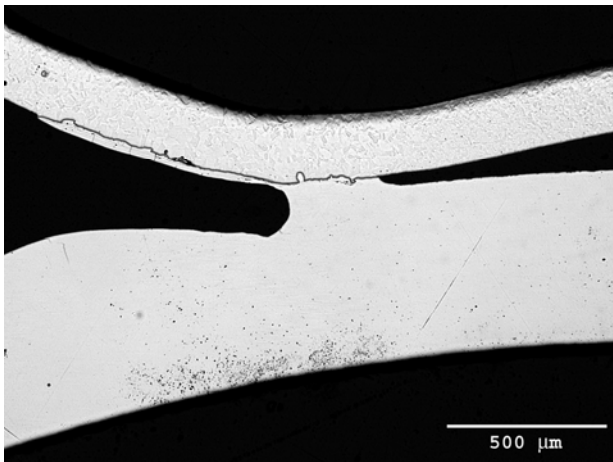
Sample B1- as polished and etched



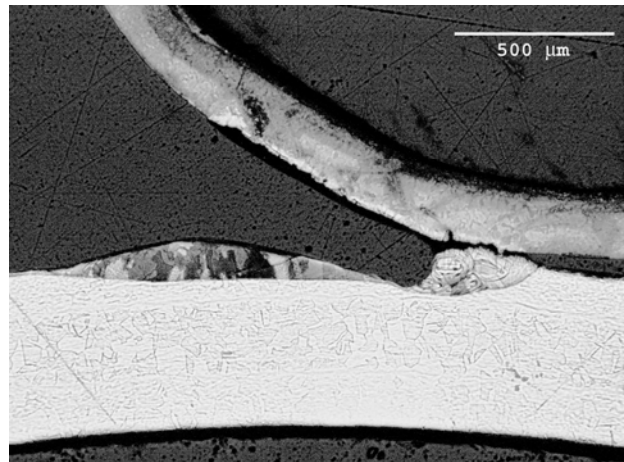
Sample B2- as polished L=0.33 mm



Sample B2- as polished and etched



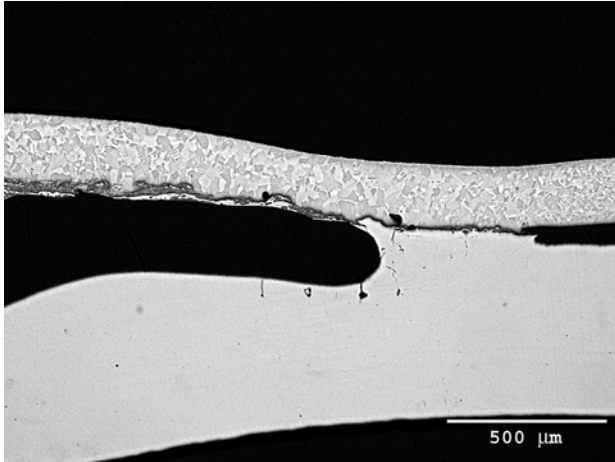
Sample B3- as polished L=0.32 mm



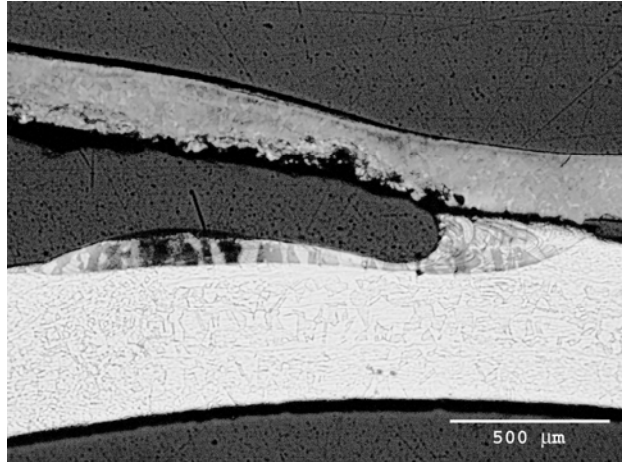
Sample B3- as polished and etched

Weld Sample C

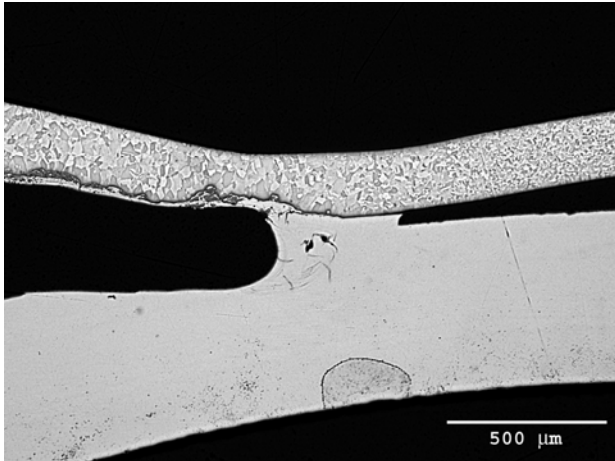
Power: 1.8 Joules; tube speed: 67 in./min; 125 pps; 0.0089" spacing



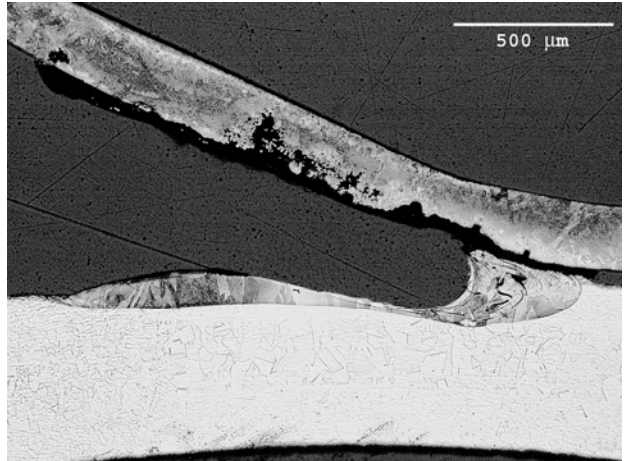
Sample C1- as polished L=0.56 mm



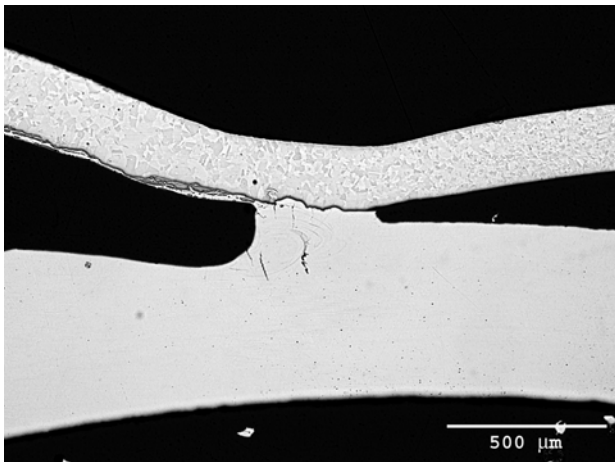
Sample C1- as polished and etched



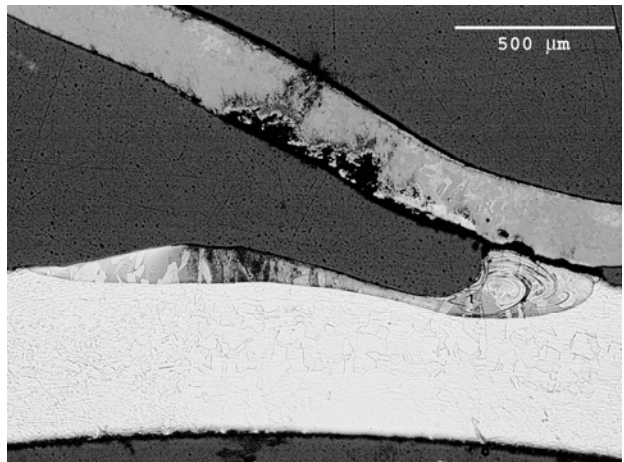
Sample C2- as polished L=0.43 mm



Sample C2- as polished and etched



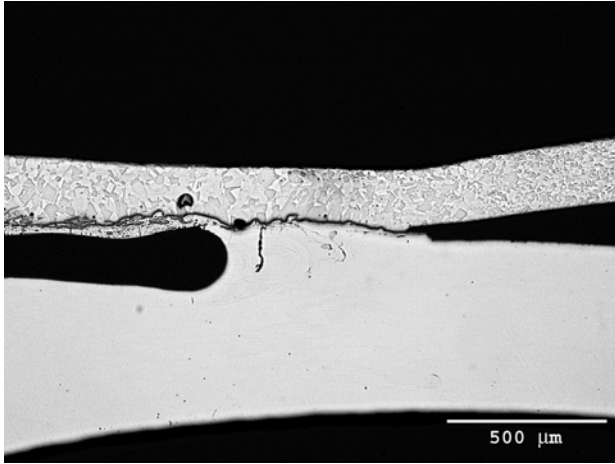
Sample C3- as polished L=0.38 mm



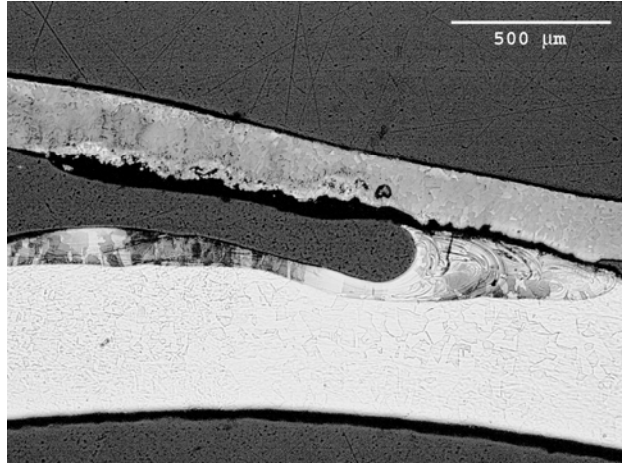
Sample C3- as polished and etched

Weld Sample D

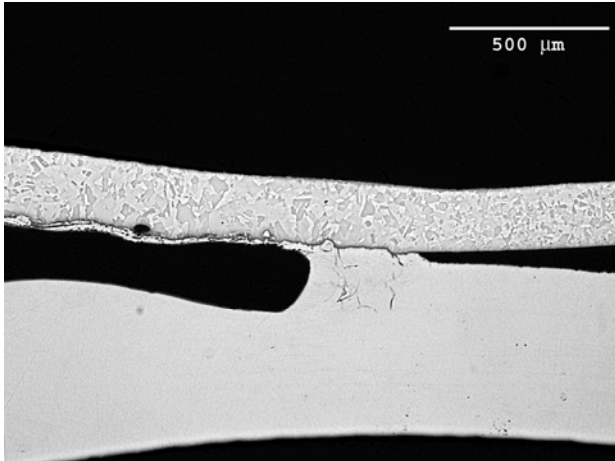
Power: 1.8 Joules; tube speed: 51 in./min; 125 pps; 0.0068" spacing



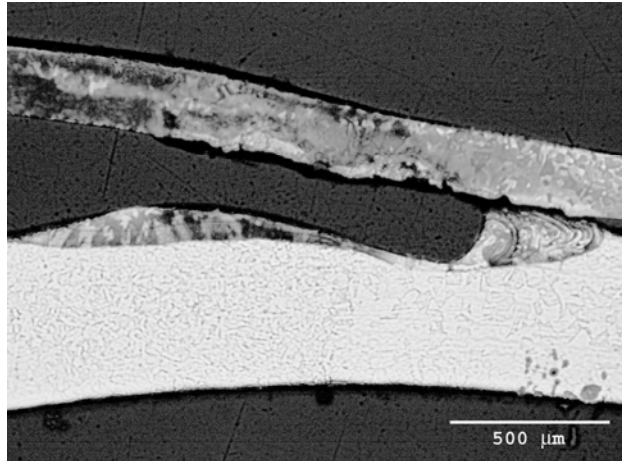
Sample D1- as polished L=0.65 mm



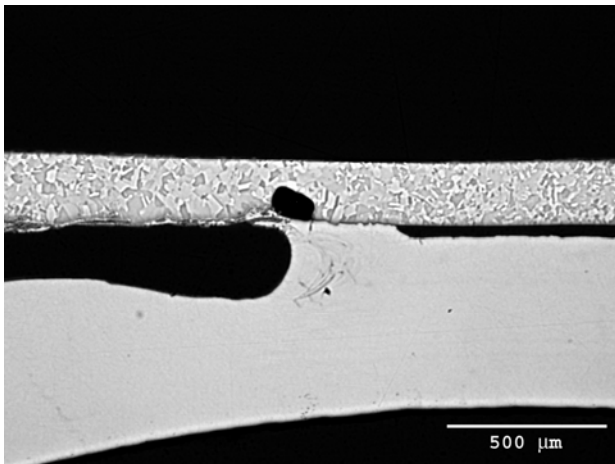
Sample D1- as polished and etched



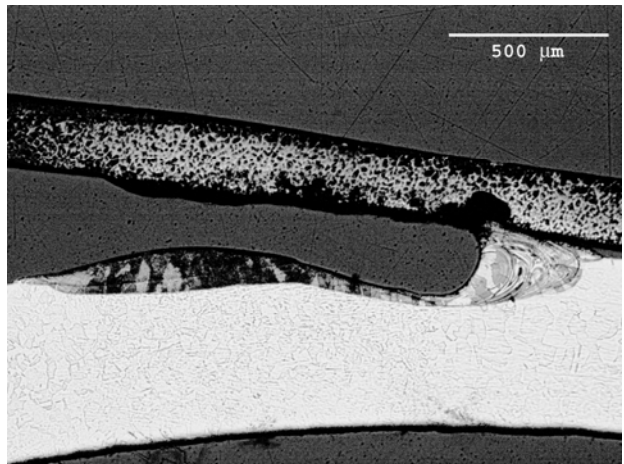
Sample D2- as polished L=0.38 mm



Sample D2- as polished and etched



Sample D3- as polished L=0.38 mm



Sample D3- as polished and etched



date: June 5, 2002

to: Dave Menicucci

from: Tim Moss

subject: Fin/Tube Thermal Analysis for RITH Solar Collector

Scott Rawlinson of Sandia National Labs did a rough thermal analysis of the heat flow from the fin to the water in a RITH solar collector. He modeled half the system assuming that both halves are the same. This model does not take into account thermal losses from either side of the fins or the tubing. The following parameters were used in the model:

- 1) The fin was 0.008" thick copper 4.625" wide
- 2) The weld properties were that of stainless steel
- 3) The weld starts 1.5 mm (0.06") from the tangential contact point between the fin and tube (as measured on RITH 3)
- 4) 100% absorption of the incident solar radiation at 1,000 W/m²
- 5) The tube parameters are 0.625" OD and 0.020" wall
- 6) The water temperature inside the tube was fixed at 100 °C
- 7) Three different weld cross-sectional areas were used, 0.2 mm (0.008"), 0.4 mm (0.016"), and 1.0 mm (0.04")
- 8) Two different tube materials were used, copper (K=380 W/m-°K) and stainless steel (K=18 W/m-°K)
- 9) Flow rates of 0.3 – 0.6 l/m in the riser, which gives a constant heat transfer coefficient of 180 W/m²-°K

The angle of incident flux, such as 4/12 vs. 6/12 or time of day, was not considered since adding an angle only changes the amount of energy incident on the fin surface. The scope of this study was to compare copper vs. stainless steel as a riser tube; changing the energy input added nothing to this.

Figure 1 shows a diagram of the system modeled. The results of the model study are shown in Table 1. The T1 temperatures in Table 1 are the estimated steady state temperatures at the outer edge of the fin, as shown in Figure 1, derived by the model. Figure 2 shows the thermal gradient of the last row of data in Table 1 from the outer edge of the fin to half the tube. Testing of RITH 6 (copper tube welded to copper fins) at Sandia showed the fin temperatures are about 108 °C midway between the tube and outer edge of the fin using copper tubing when the water temperature is 100 °C. Looking at Figure 2, the fin temperature at the midpoint is about 10 °C cooler than T1 at the outer edge. T1 is 138°C so the midpoint would be about 127 °C. Comparing the model data to the data from RITH 6 shows the model is not in close agreement, but it is in the right ballpark.

The data from the model indicates that doubling weld area will not have much effect. This can be explained by looking at cross-sectional areas and heat conductivity. When the fin and tube were both copper (therefore the same heat conductivity), having a weld area thicker than the fin did not increase heat flow to the water. The fin itself can only conduct so much heat and changing the weld area does not change the amount of heat being conducted by the fin. Changing the tube from copper to stainless steel lowered heat conductivity of the tube by a factor of 24; therefore, the main constriction to heat flow is the tube itself. Following this analogy, the weld area needs to be 24X the fin thickness in order to not inhibit the flow of heat from the fin to the water. At

present the only way to achieve this would be to plasma spray aluminum or copper in the area of the weld. This would increase the weld area from about 2X the fin thickness presently seen to about 40X the fin thickness. The aluminum, or copper, would also be more conductive than the weld because the weld has properties close to stainless steel.

An alternative to increasing the weld area would be to decrease the fin width and increase the number of risers in each array. This would not increase the array size but would increase the amount of energy being transferred to the water and lower fin temperatures that would decrease thermal losses. At present, no work has been done to determine how many risers, or the width of the fins, are needed until after testing of the solar array with stainless steel risers is completed.

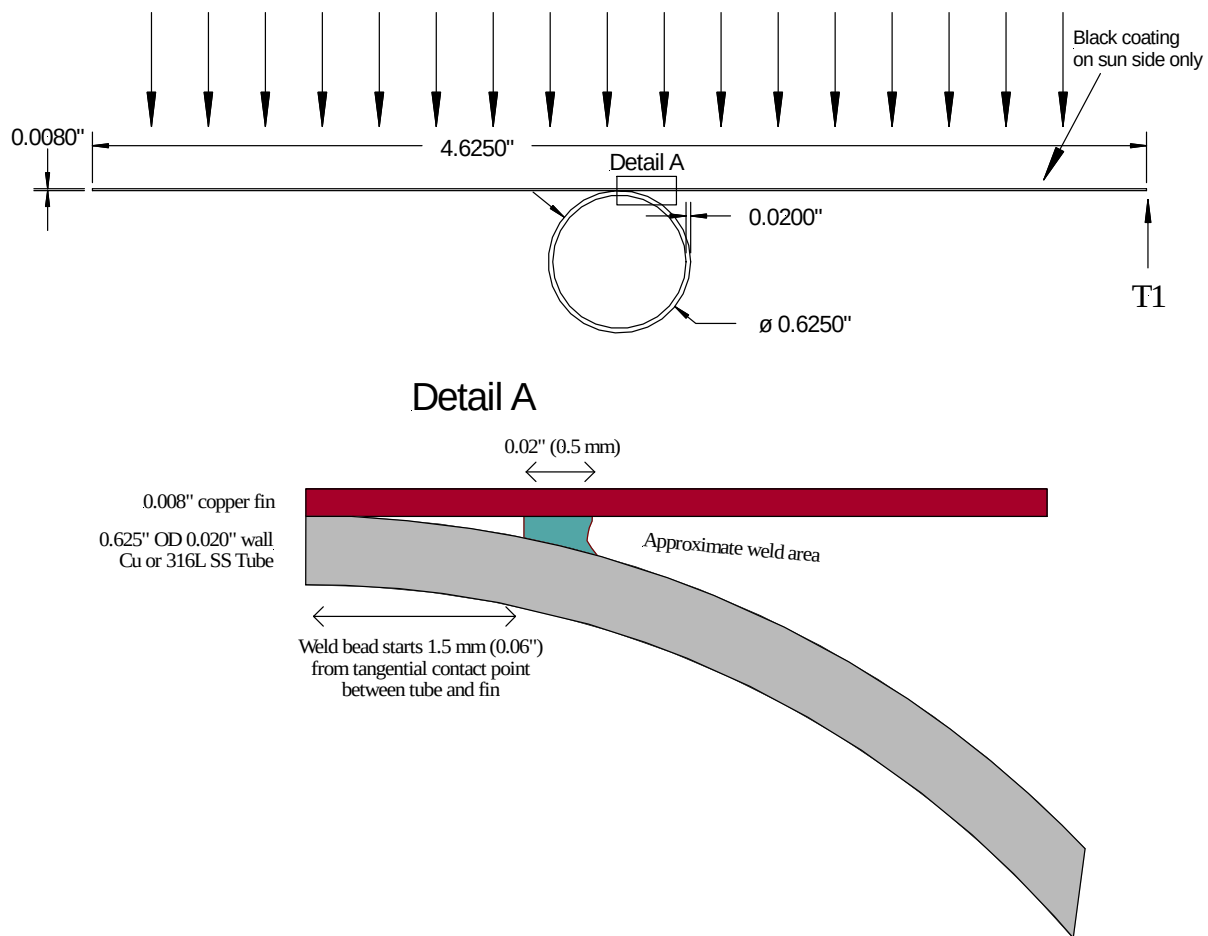


Figure 1. Cross section of a tube/fin section with a detailed view of the weld area.

Table 1. Results of fin/tube analysis.

Tube Material	Weld Area	T1 Temperature
Cu	0.2 mm (0.008") SS	140 °C
SS	0.2 mm (0.008") SS	163 °C
Cu	0.4 mm (0.016") SS	138 °C
SS	0.4 mm (0.016") SS	161 °C
Cu	1.0 mm (0.04") SS	137 °C
SS	1.0 mm (0.04") SS	158 °C

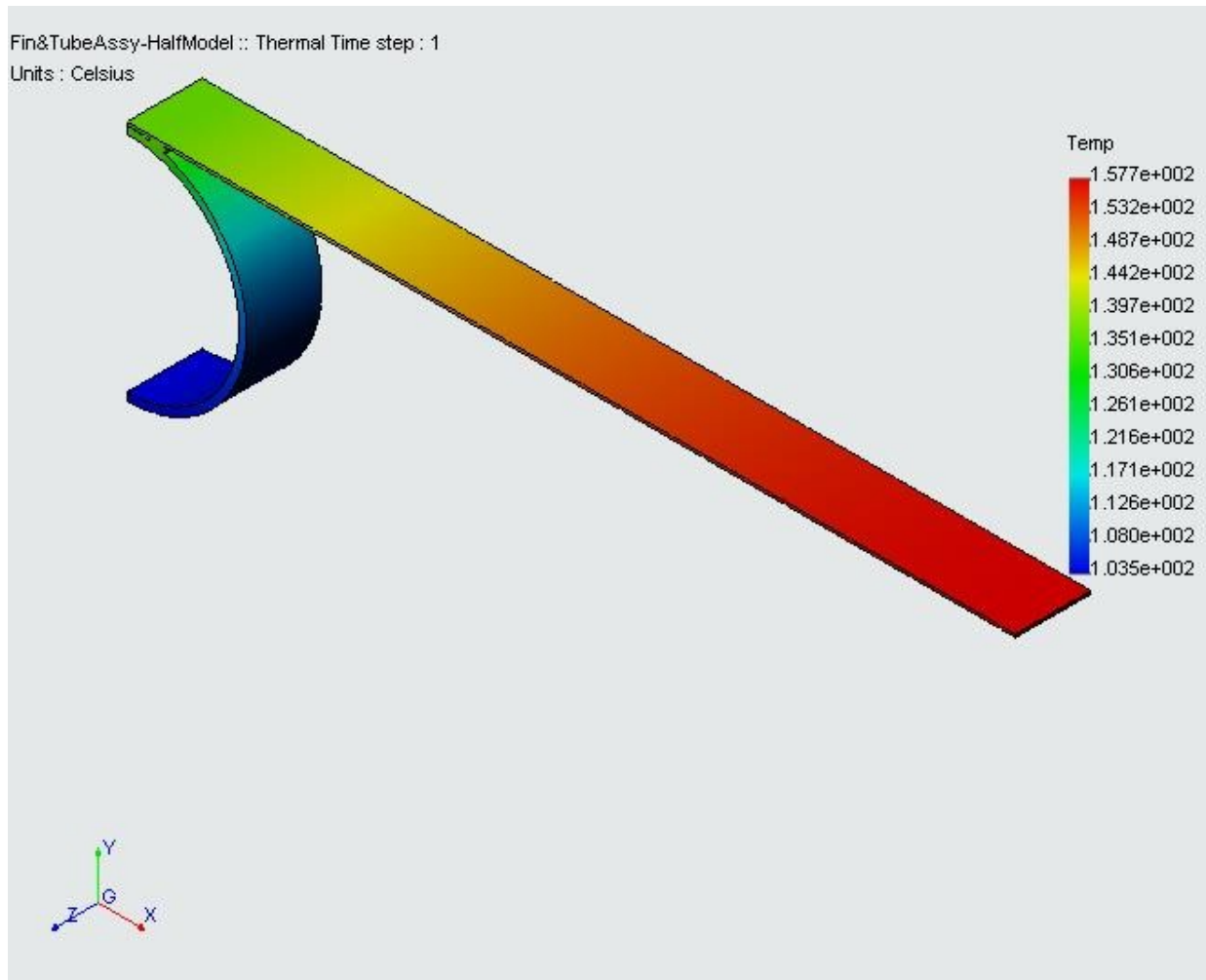


Figure 2. Thermal gradient along the fin and tube from the last data presented in Table 1.

Appendix G.
Test Results and Post-Mortem
Analysis of RITH 3

RITH 3 was installed in a Calnex model home at Gold Canyon. Before the test, the Sandia National Laboratories (SNL) and the Salt River Project (SRP) team outlined the questions to be answered by the field test. They are outlined below.

RITH 3 TESTING CRITERIA AND RELATED INFORMATION

Developed by E. Palamino, R. Stephenson, and D. Menicucci on February 9, 1999

QUESTIONS TO BE ANSWERED BY RITH 3 FIELD TEST:

- 1) How does RITH perform in Phoenix?
 - Seasonal performance
 - With various loads (small two-person family, large four-person family, morning/evening load, etc.)
 - Characterize Performance = $f(\text{weather})$
 - Document energy savings
- 2) How well does it install?
 - How long does it take
 - How easy is it to install (how many people, how much equipment, etc.)
 - What does it cost to install (any special equipment needed)
 - What is the reaction of the tradesmen/builder
- 3) What is the reliability of the system?
 - Any leaks in the system
 - Any roof leaks
 - Any freezing or cold-weather problems
 - Any problem with extended period of non-use (i.e., vacation time) in hot weather
- 4) What is the reaction to the system aesthetics?
 - Potential home buyers
 - Salespeople
 - Builder

APPROACH TO ANSWERING THE QUESTIONS

- (1) Install computerized load management system (computer) and monitoring equipment to control the load and to record the results. Load profiles will be determined from the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE). We will want to test each of two to three load profiles (two-person family, four-person family, morning/afternoon load) in each of the four seasons. We will also want to test out stagnation conditions, especially during hot season. The computer will require a phone line to allow TDT personnel to be able to collect data remotely, change load profiles, and monitor status. Analysis will include computing total energy used, total solar heat produced, and total backup energy used. Costs savings will also be computed.

- (2) Installation ease will be assessed through visual oversight during the installation and through review of the videotape of the installation. Video should include one fixed shot of the whole scene and one mobile camera to get closeup action of specific activities. Additional information will be gathered by interviewing the installers. Analysis will include the total time for installation and special materials used, and the cost of the activity based on typical prices.
- (3) Reliability will be assessed by visual inspection of the system over time and by talking with persons who are at the site on a regular basis. A log book, which is kept on site, will also be carefully inspected for indications of reliability problems, especially during worst-case tests such as summer stagnation.
- (4) The system will be on display on a home. People who view the system will be asked to comment on the aesthetics of the system. If needed, special display times can be set up during which people can be asked to comment on the system appearance.

CRITERIA FOR THE RITH 3 FIELD TEST

- (1) Loads must be controlled
- (2) Must be installed in a typical location in Phoenix
- (3) TDT must have virtually unlimited access to the site
- (4) Must be visible to people, especially potential home buyers and builders
- (5) Must be installed in a typical new subdivision home
- (6) Liability of SRP and Technology Development Team (TDT) must be minimized in selecting a site
- (7) Need a one- to three-year test period

OPTIONS FOR RITH 3 FIELD TEST

- (1) Model home (satisfies criteria # 1, 2, 3, 4, 5, 6(?), 7(?))
- (2) SRP employee's home (satisfies criteria # 2, 4 (?), 5)
- (3) Buy a new home (satisfies criteria #1-7, but is very expensive)

THE FIELD TEST

The test period started on January 1, 2001, and ended on April 30, 2002. The roof had a 5/12 pitch, the tank size was 72 gallons, and the collector area was 2.85 m². The RITH 3 solar water heater as connected provided about 57% of the hot water required during the test period. This would amount to saving 1740 kWh per year. If the RITH 3 solar water heater had been located within 20 feet of the electric water heater, instead of 79 feet, it probably would have provided in excess of 85% of the hot water required during the test period. This would amount to saving 2915 kWh per year. A data summary is shown in Table 1.

Table 1. Data summary of RITH 3 testing.

Data is based on full month of data. If not measured on a day, an average day is inserted.

DATA SUMMARY:	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Ave.
Ave. Hot Water Load/day:	kWh	10.47	14.84	14.42	13.20	11.52	8.46	5.18	5.16	5.13	6.74	8.19	10.27	10.46	10.01	9.49	8.06	9.48
Ave. Solar Fraction:	%	5.7	19.3	29.6	37.4	57.7	72.5	82.8	83.5	80	38.9	17	2.6	24	41.1	51.8	71.27	44.70
Total Daily Solar Irradiance:	kWh/m ²	136.4	143.9	188.5	195.5	225.2	216.5	186.3	208.3	202.6	176.2	141.4	135.4	134.7	159.4	206.5	211.3	179.26
Ave. High Daily Temperature:	°F	63.9	66.3	76.2	84.6	102.5	108.9	107.6	106.2	102.8	88.8	73.5	61.8	65.1	72.7	76	89.9	84.2
Ave. Low Daily Temperature:	°F	41.5	42.4	49.4	54.6	68.4	74.1	78.6	76.1	74.4	63.6	51.7	40	42.5	46	47.7	61.2	57.0
Total Hot Water Load:	kWh	210.5	379.0	447.0	396.1	357.1	253.7	160.5	159.9	153.8	209.0	239.6	318.4	324.4	280.2	294.1	241.9	276.57
Total Hot Water at TSH:	kWh	77.0	126.0	179.2	192.6	247.6	219.1	171.4	171.6	156.2	114.4	83.2	67.9	77.3	113.8	151.4	171.6	145.02
Fraction of Load at TSH:	%	36.6	33.2	40.1	48.6	69.3	86.4	106.8	107.3	101.6	54.7	34.7	21.3	23.8	40.6	51.5	70.9	57.97
Expected Solar Fraction:	%	42.0	55.4	65.5	83.7	97.1	114	116.4	124.2	116.5	87.3	54.9	42.7	42.0	55.4	65.5	83.7	77.89
Ave. Solar Radiation/Day:	kWh/m ² /d	4.35	5.14	6.08	6.52	7.26	7.22	6.33	6.72	6.75	5.66	4.62	4.37	4.35	5.69	6.66	7.05	5.92
Expected Ave. Solar Radiation/day:	kWh/m ² /d	4.61	5.66	6.44	7.76	8.06	7.92	7.64	7.43	7.19	6.40	5.14	4.37	4.61	5.66	6.44	7.76	6.44
Ave. Hot Water used/day:	gals.	80.8	111.8	126.3	127.7	132.4	104.5	82.1	81.7	81.6	80.7	80.7	80.9	80.9	80.9	80.7	80.7	93.40
Total Hot Water at TSHO:	kWh	69.1	128.2	210.5	225.3	285.9	235.9	92.6	225	209.6	160.2	181.8	99.2	108.2	149.7	198.2	101.9	167.58
Fraction of Load at TSHO:	%	32.8	33.8	47.1	56.9	80.1	93.0	57.7	140.7	136.3	76.7	75.9	31.2	33.4	53.4	67.4	42.1	66.15
Expected Solar Fraction:	%	42.0	55.4	65.5	83.7	97.1	114.0	116.4	124.2	116.5	87.3	54.9	42.7	42.0	55.4	65.5	83.7	77.89
Total Days in test period:	458	20	28	31	30	31	30	31	31	30	31	30	31	31	28	31	14	
Total days data used for performance:	383	20	24	31	30	31	4	13	31	30	12	22	31	31	28	31	14	
Stagnation Testing:	36						26	10										
Water on in house.	24										16	8						
Electric water heater load testing:	4		4															
Days data not saved (vacation, lost):	11							8			3							
Percentage of time data measured:	97.6	%																

Hot water load set for more than nominal 80 gallons per day.

Performance based on water temperature measured at 20 feet from solar water heater.

Figure 1 shows the schematic of how RITH 3 was connected to the model home plumbing and how it was instrumented for testing.

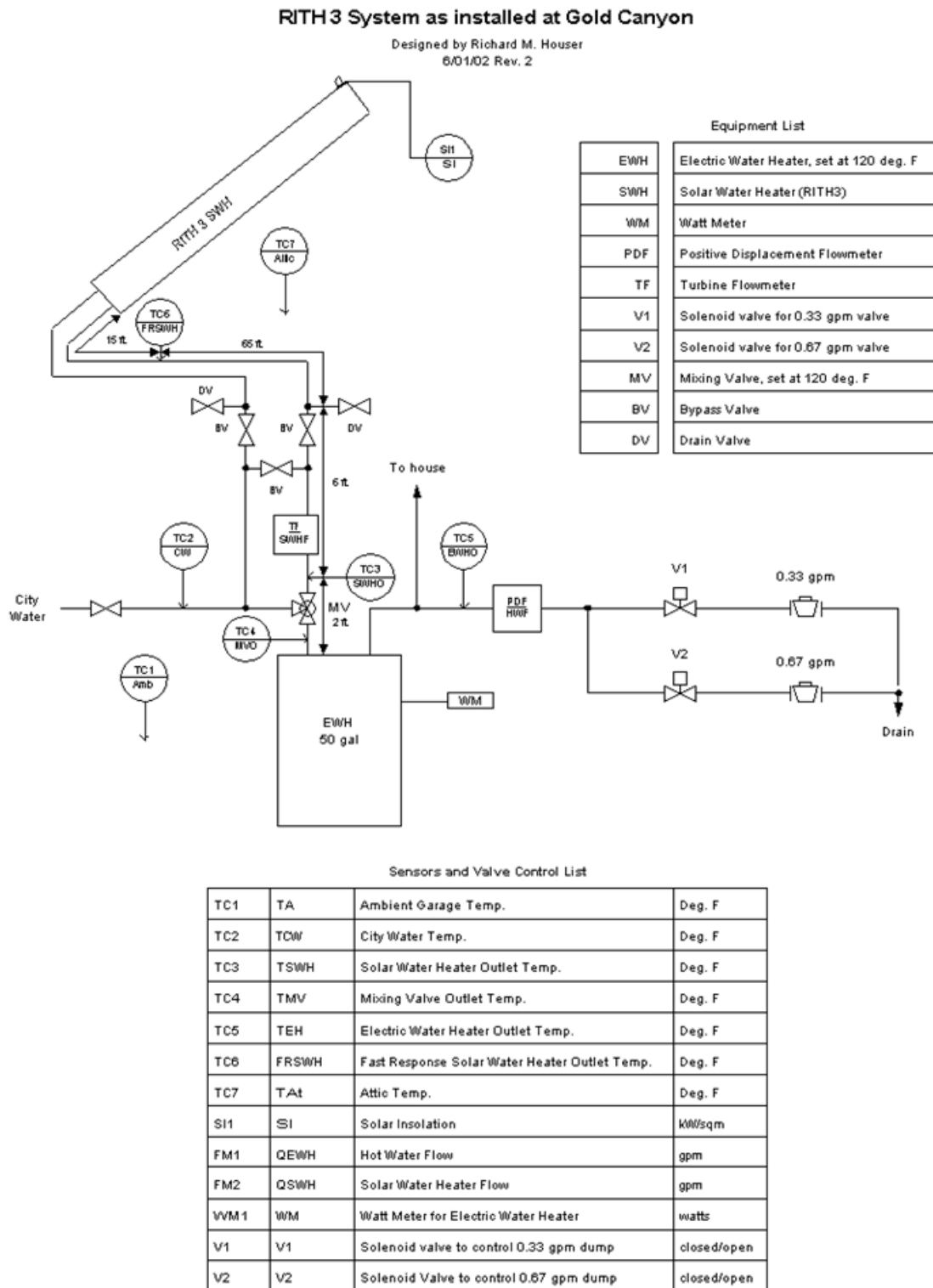


Figure 1. Schematic of how RITH 3 was plumbed into the model home and instrumented for testing.

The system monitoring diagram is found in Figure 2.

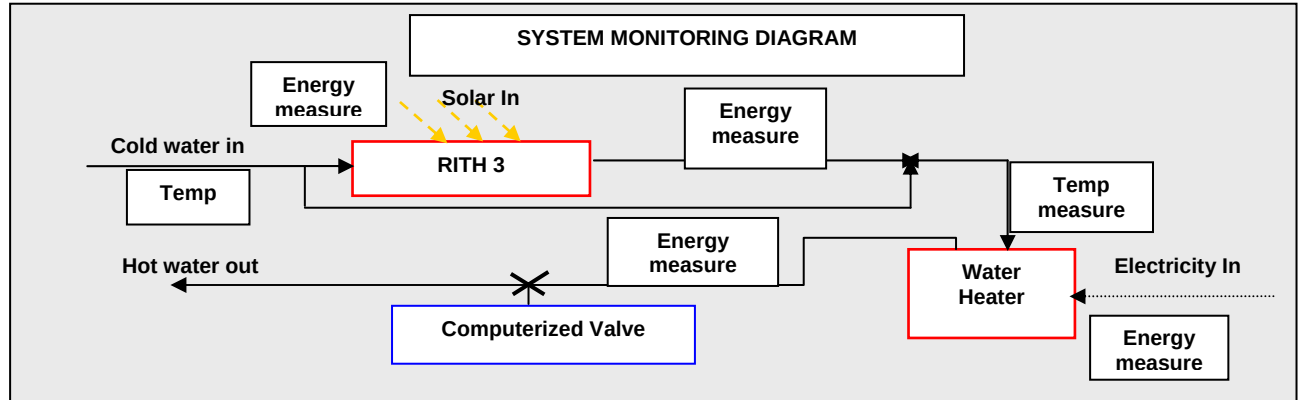


Figure 2. System monitoring diagram.

Stagnation tests were conducted on RITH 3 to determine if the system could avoid boiling conditions in a worst-case condition in which a collector was left operational in maximum solar conditions in June and no water was drawn from it. The results of these tests are found in Figure 3. As can be seen, the system never achieved boiling temperatures and thus operated exactly to design specifications.

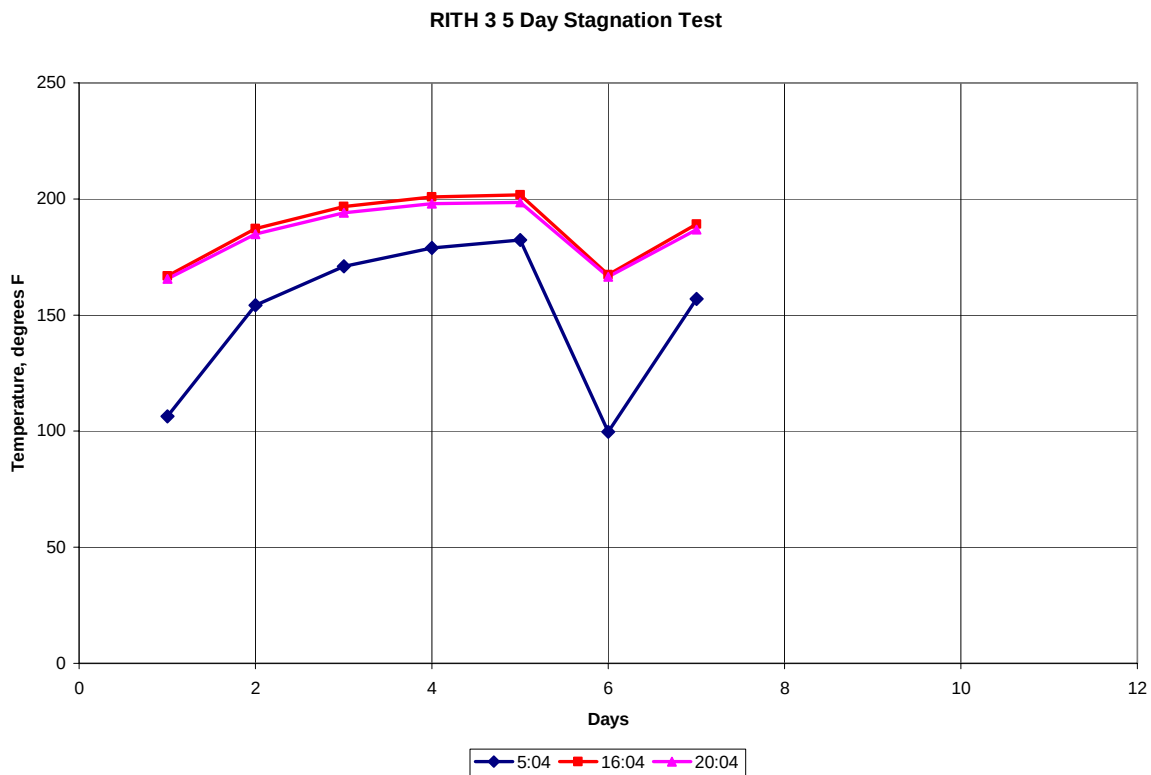
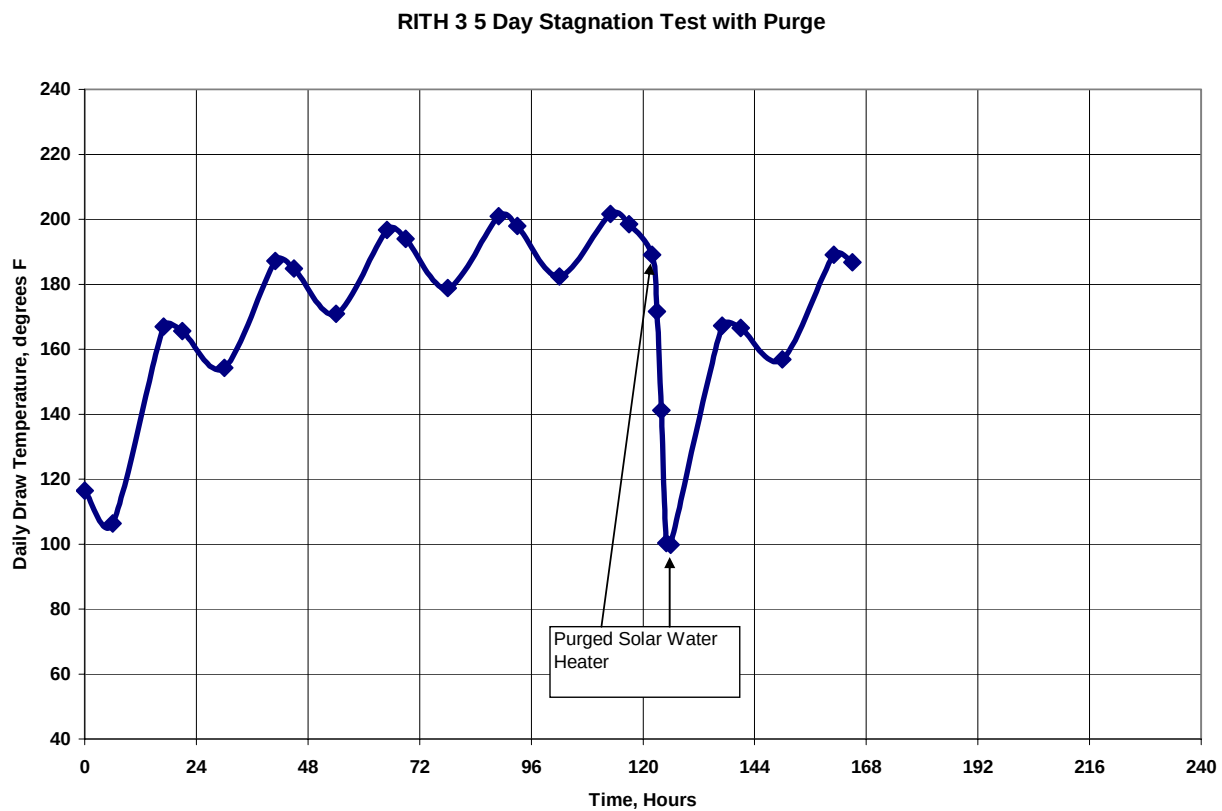


Figure 3. Results of RITH 3 five-day stagnation tests.

This is a memo regarding the testing and analysis of RITH 3.



Sandia National Laboratories

Operated for the U.S. Department of Energy by
Sandia Corporation
Albuquerque, New Mexico 87185-

date: July 9, 2002

to: David Menicucci
Ernie Palomino
Ric Stephenson
Mike Newman

from: Tim Moss

subject: Post-Test Analysis of RITH 3

RITH 3 was tested from January 2001 to April 2002 at Gold Canyon, AZ. This was a one-piece unit with a ≈ 70 -gallon epoxy-coating lined steel tank (18" OD by 64" length), 2.85 m^2 (30.7 ft^2) absorber, $84" \times 60"$ glazing, $3/4"$ copper tube risers, and 1" copper tube headers. Figure 1 shows a sketch of the RITH 3 solar absorber along with some dimensions and locations of the samples removed for inspection.

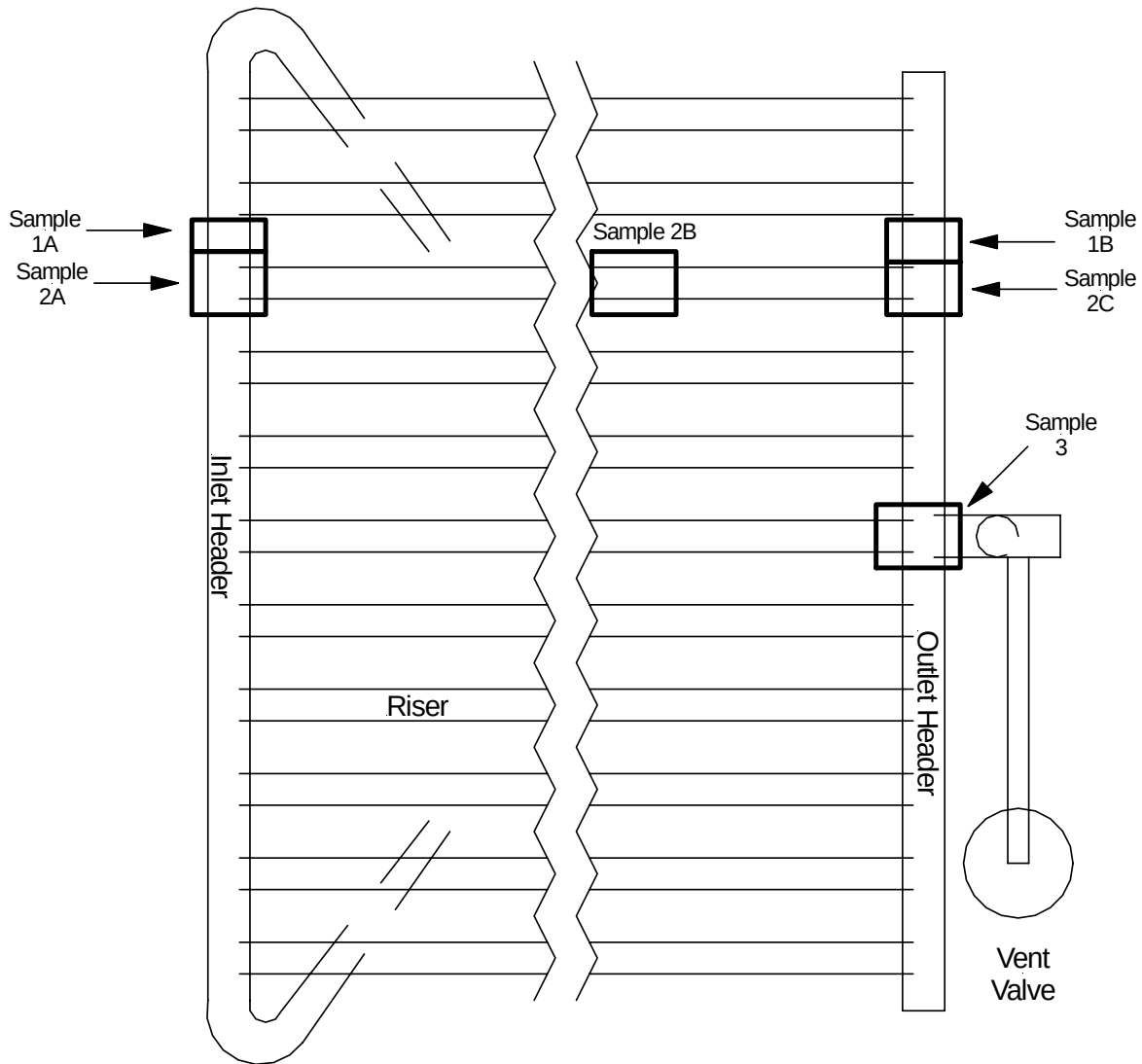
On June 5, 2002, the solar absorber for RITH 3 was cut open to look for internal corrosion of the copper tubing used in the solar absorber. Figures 2 and 3 show the front and back, respectively, of the absorber after being removed from the RITH 3 unit. Figures 4 through 10 show pictures of the samples after being removed from the absorber and cross-sectioned. These pictures show very little corrosion has taken place inside the copper tubing. Sample 3 shows the highest level of corrosion found in the solar collector. Figure 9 shows some corrosion on the outside of sample 3. Figure 10 shows the inside of sample 3, which also shows some corrosion.

Figure 11 shows the vent valve used for RITH 3 before it was removed, which shows it had leaked for some time. The vent valve was taken apart (Figure 12). The stem for the release valve was broken and this is probably why it had leaked. This does not cause much concern since later designs of the RITH system do not use a vent valve.

The inlet into the storage tank from the solar absorber was also removed for inspection. Figures 13 and 14 show pictures of the copper tubing inlet into the hot water tank from the solar collector. Very little corrosion has taken place. There is one disadvantage for the copper tube inserted inside the tank, which is it can have copper corrosion on both sides of the tube since the water is on both sides. The copper tubing leading to the inlet tube shown in Figure 15 was also removed and cut open for inspection. Again, very little corrosion has taken place inside the copper tubing.

The corrosion lab looked at all the samples removed from the RITH 3 solar absorber. It was found that all the corrosion was surface only with no evidence of pit corrosion. When the corrosion layer is removed there is fresh copper underneath with no signs of a pit underneath.

RITH 3 array and sample locations



Riser: 3/4" copper tube, 0.040 wall
 Header: 1" copper tube, 0.030" wall
 fin: 5.25" wide, 0.008" thick, black coating on sun side only
 Overall array size: 183 cm (72") x 143.5 cm (56.5")
 Collector area: 176 cm (69.25") x 143.5 cm (56.5")
 Number of risers: 11
 Spacing between risers: 10.7 cm (4.25")

Figure 1. Sketch of RITH 3 showing dimensions and sample cutout locations.



Figure 2. Front of absorber, left side is the outlet header.



Figure 3. Backside of absorber, right side is outlet header.



Figure 4. Sample 1A – showing inside of copper inlet header.



Figure 5. Sample 1B – showing inside of copper outlet header.

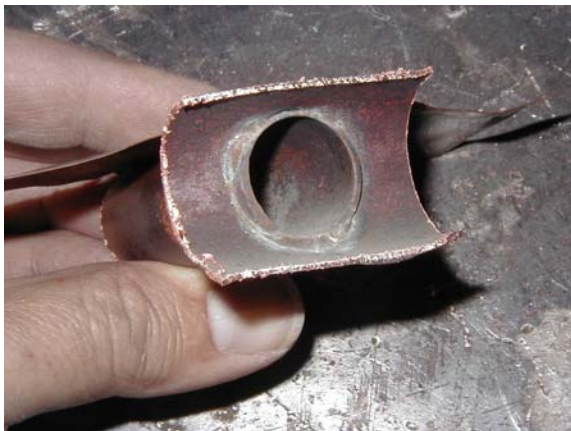


Figure 6. Sample 2A – looking down riser tube with some of the inlet header still attached.

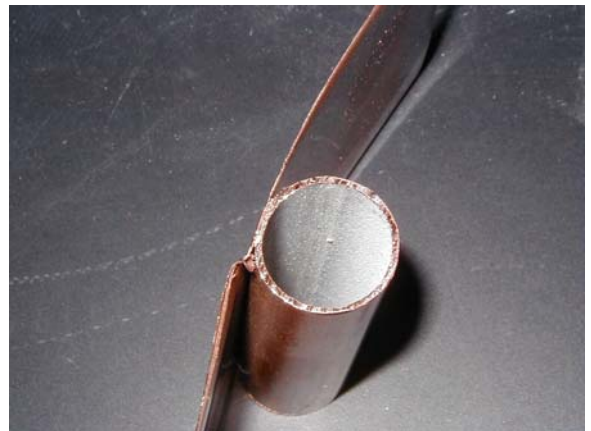


Figure 7. Sample 2B – looking down riser tube.



Figure 8. Sample 2C – looking down riser with cross section of the header still attached.

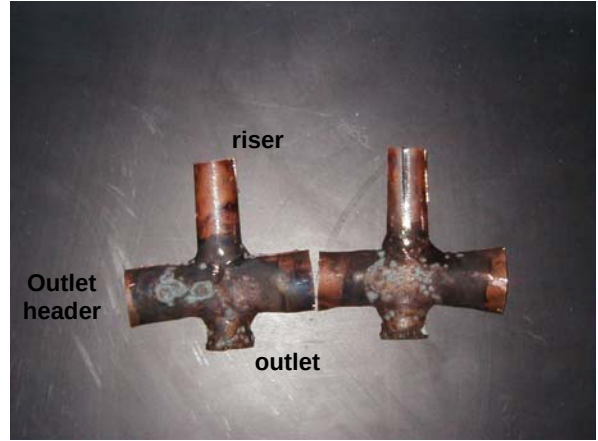


Figure 9. Sample 3 – showing outside half-sections, the riser tube is vertically up.



Figure 10. Sample 3 – showing inside half-sections with rise tube vertically up.



Figure 11. Vent valve showing the effects of a long-term leak through the valve.



Figure 12. The inside of the vent valve. Notice the broken rod that caused the valve to leak.



Figure 13. Inlet into tank from the solar absorber.



Figure 14. Another view of the inlet into the tank from the solar absorber.



Figure 15. Copper tube leading to the tank inlet shown in Figures 13 and 14.

Appendix H.

Test Results From RITHs 4 and 5

RITH 4 TESTS

RITH 4 and RITH 5 systems were installed on a Calex model home in the Phoenix area. RITH 4 was tested from November 1, 2001, to June 30, 2002, at Johnson Ranch. RITH 5 was tested from April 12, 2002, to April 16, 2003, at Gold Canyon. These two systems were identical, except RITH 4 was built as a one-piece unit and needed a crane for installation. RITH 5 was built as a two-piece unit and was installed by regular tradespeople without a crane. Because it was a two-piece unit, flex hoses were used to connect the storage tank to the collector. RITH 4 used tubing to connect the storage tank to the collector. Both RITHs were plumbed and instrumented the same as for RITH 3. Both were installed on a south-facing roof with a 5/12 pitch. Both were installed above the garage where the domestic electric hot water heater was so the distance between the heater and the RITH unit was about 20 feet. Both were tested under a simulated hot water load of 80 gallons per day.

Figure H-1 is a graph of the predicted and actual percentage of the hot water load of RITH 4 during the test period. It delivered 1,526 kWh of hot water to the home with an average sunlight-to-delivered hot water efficiency of 36% over the 8-month test period.

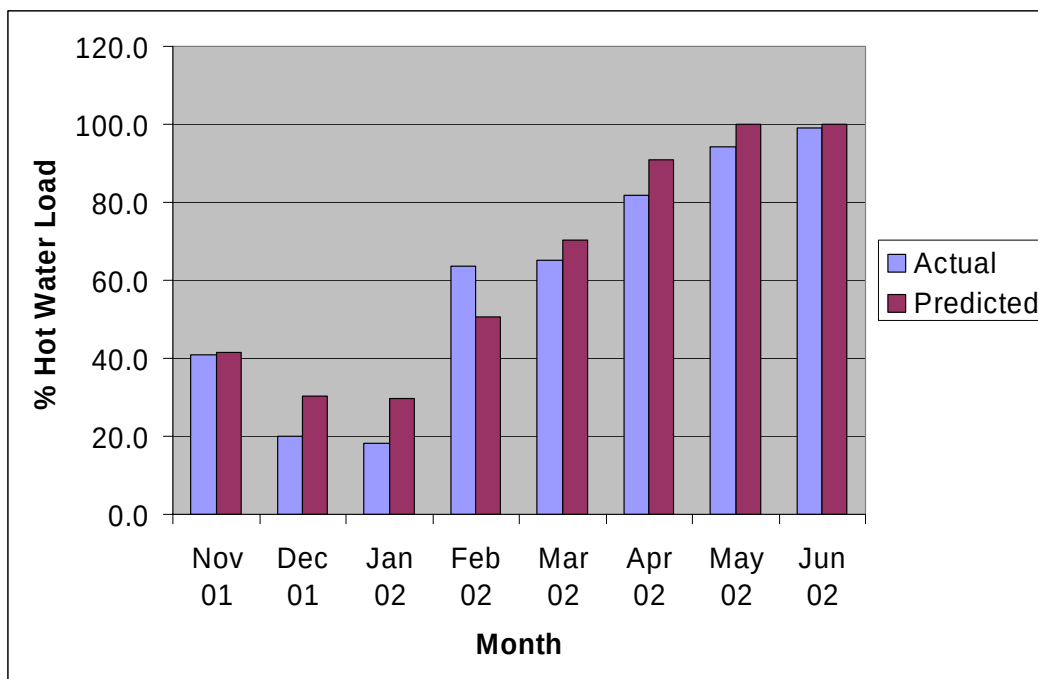


Figure H-1. Chart showing the expected and actual percentage of hot water load supplied by RITH 4.

Outlined below is a typical data summary of RITH 4 performance as recorded by the development team.

NOVEMBER DATA SUMMARY FOR RITH 4 AT JOHNSON RANCH

Monthly Summary: This was the first month that the RITH 4's performance was monitored and it produced 68.6% of the energy needed to heat water in the simulated Calnex home. The expected amount of energy that the RITH 4 is expected to produce at this time of year is 45.2%. The solar radiation for the month was 4.97 kWh/sqm/day which was 3.3% less than the long-term expected average of 5.14 kWh/sqm/day. The solar water heater performed better than expected even with the unexpected 3.3% decrease in solar radiation.

SYSTEM INFORMATION:

Location:	Calnex Homes
Test startup date:	Oct. 19, 2001
Data reporting period:	November 19, 2001 to November 30, 2001
Orientation of RITH 4:	South, 5/12 pitch
RITH tank size:	72 gallons
Collector area:	2.85 sq meters (30.7 sq. feet)
Distance, RITH 4 to EWH	18 feet
Average hot water used per day	80 gallons

DATA SUMMARY:

Maximum RITH 4 hot water delivered:	4.21 kWh	occurred on 3-Nov-01
Maximum solar fraction:	68.9 %	occurred on 3-Nov-01
Maximum daily solar irradiance:	5.96 kWh	occurred on 2-Nov-01
Maximum average ambient temperature:	82.5 Deg F	occurred on 3-Nov-01
Total hot water heating required:	228.8 kWh	
Total hot water heat from RITH 4:	87.0 kWh	
Monthly fraction of load from RITH 4:	40.8 %	90.2 % of expected
Expected fraction of load from RITH 4:	45.2 %	
Average daily site ambient temperature:	69.6 Deg F	
Average daily solar radiation on RITH 4:	4.97 kWh	96.7 % of expected
Expected daily solar radiation on RITH 4:	5.14 kWh	
Average daily hot water load:	7.63 kWh	

Definition of Terms:

Solar Fraction is the percentage of the total hot water load supplied by the solar system

Fraction of Load is the same as the *solar fraction*

Solar Irradiance is the total amount of solar energy received on the RITH 4 collector

Ambient temperature is the average air temperature at the site in the shade

Expected solar fraction is an estimate of the solar fraction for the month based on Sandia's model

Expected solar radiation is an estimate of the radiation on RITH 4 based on long-term measurements of solar radiation in the Phoenix

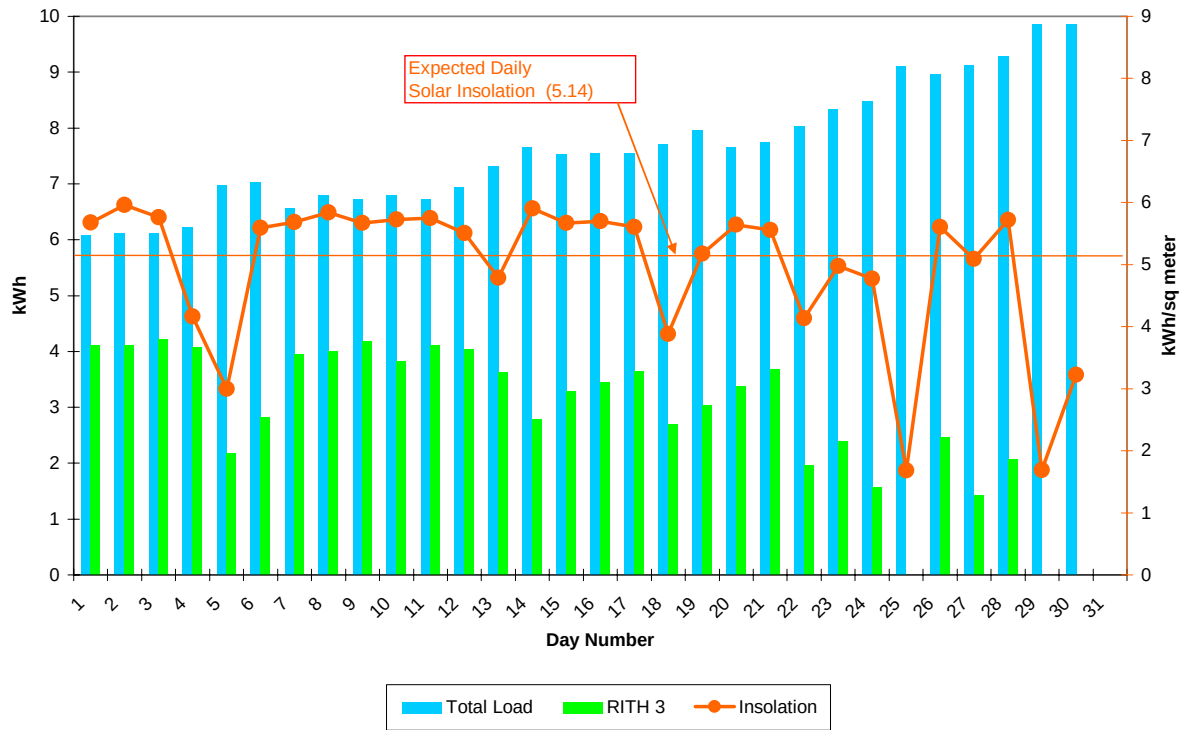
Month of November 2001

30 days	Avg. Daily Amb Temp. (F)	Total Daily Insol. (kWh/m2)	Total Electric Input (kWh)	RITH's Contribu- tion (kBTU's)	RITH's Contribu- tion (kWh)	Total Hot Water Load (kWh)	RITH's Solar Fraction (%)	SWH Storage Level (kBtu's)
Date								
1-Nov-01	79.6	5.68	1.96	20.7	4.11	6.07	67.7	29.9
2-Nov-01	78.9	5.96	1.99	20.8	4.12	6.11	67.4	29.6
3-Nov-01	82.5	5.76	1.90	21.1	4.21	6.11	68.9	29.1
4-Nov-01	82.3	4.16	2.15	19.5	4.07	6.22	65.4	21.0
5-Nov-01	73.7	3.00	4.80	13.5	2.17	6.98	31.1	13.1
6-Nov-01	75.8	5.59	4.20	16.1	2.83	7.03	40.2	29.4
7-Nov-01	76.0	5.69	2.61	20.9	3.95	6.56	60.2	28.7
8-Nov-01	78.2	5.84	2.80	20.9	4.01	6.80	58.9	29.9
9-Nov-01	73.5	5.67	2.53	21.1	4.19	6.72	62.4	27.9
10-Nov-01	76.6	5.73	2.97	20.4	3.81	6.79	56.2	29.6
11-Nov-01	75.7	5.75	2.62	21.1	4.12	6.74	61.1	28.7
12-Nov-01	74.6	5.51	2.89	20.5	4.04	6.93	58.2	27.4
13-Nov-01	69.9	4.78	3.68	18.7	3.63	7.31	49.6	22.9
14-Nov-01	66.0	5.90	4.88	18.1	2.78	7.66	36.3	27.2
15-Nov-01	68.9	5.67	4.25	19.1	3.28	7.53	43.6	26.7
16-Nov-01	70.9	5.70	4.11	19.5	3.44	7.55	45.6	27.3
17-Nov-01	71.8	5.61	3.89	19.9	3.65	7.54	48.4	26.7
18-Nov-01	70.9	3.88	5.03	16.3	2.68	7.71	34.8	16.0
19-Nov-01	72.0	5.18	4.93	16.7	3.04	7.96	38.1	24.6
20-Nov-01	70.7	5.64	4.28	19.3	3.38	7.66	44.1	26.5
21-Nov-01	70.2	5.56	4.06	19.4	3.68	7.74	47.5	25.4
22-Nov-01	69.0	4.14	6.08	15.4	1.96	8.04	24.4	15.0
23-Nov-01	66.3	4.98	5.96	15.0	2.39	8.34	28.6	21.5
24-Nov-01	59.9	4.78	6.91	14.2	1.57	8.48	18.5	16.9
25-Nov-01	58.2	1.68	9.52	5.1	0.00	9.11	0.0	5.3
26-Nov-01	59.3	5.61	6.49	14.2	2.47	8.96	27.6	24.7
27-Nov-01	53.2	5.09	7.71	16.1	1.42	9.13	15.6	18.6
28-Nov-01	55.1	5.72	7.21	15.7	2.07	9.28	22.3	22.4
29-Nov-01	52.4	1.69	10.71	5.6	0.00	9.86	0.0	3.9
30-Nov-01	57.4	3.22	10.24	6.7	0.00	9.86	0.0	11.1
Daily Average	69.6	4.97	4.78	17.0	2.90	7.63	40.8	22.9
Totals	n/a	149.2	143.4	511.4	87.0	228.77	n/a	n/a
Minimum	52.4	1.68	1.90	5.1	0.00	6.07	0.0	3.9
Maximum	82.5	5.96	10.71	21.1	4.21	9.86	68.9	29.9

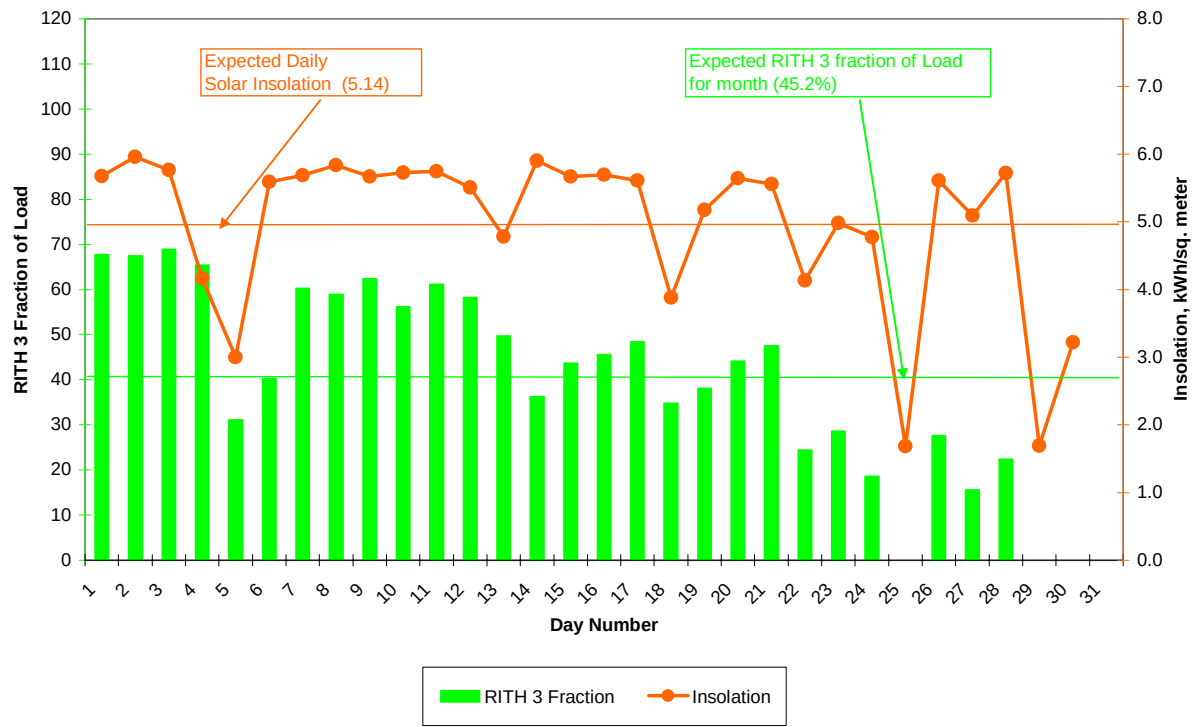
ESTIMATED SAVINGS FOR RITH 4 (November 2001)

	Savings at \$0.05/kWh	Savings at \$0.10/kWh	Savings at \$0.15/kWh	Cumulative savings at \$0.05/kWh	Cumulative savings at \$0.10/kWh	Cumulative savings at \$0.15/kWh
Date	(\$)	(\$)	(\$)	(\$)	(\$)	(\$)
1-Nov-01	\$0.21	\$0.41	\$0.62	\$0.21	\$0.41	\$0.62
2-Nov-01	\$0.21	\$0.41	\$0.62	\$0.41	\$0.82	\$1.23
3-Nov-01	\$0.21	\$0.42	\$0.63	\$0.62	\$1.24	\$1.87
4-Nov-01	\$0.20	\$0.41	\$0.61	\$0.83	\$1.65	\$2.48
5-Nov-01	\$0.11	\$0.22	\$0.33	\$0.93	\$1.87	\$2.80
6-Nov-01	\$0.14	\$0.28	\$0.42	\$1.08	\$2.15	\$3.23
7-Nov-01	\$0.20	\$0.40	\$0.59	\$1.27	\$2.55	\$3.82
8-Nov-01	\$0.20	\$0.40	\$0.60	\$1.47	\$2.95	\$4.42
9-Nov-01	\$0.21	\$0.42	\$0.63	\$1.68	\$3.37	\$5.05
10-Nov-01	\$0.19	\$0.38	\$0.57	\$1.87	\$3.75	\$5.62
11-Nov-01	\$0.21	\$0.41	\$0.62	\$2.08	\$4.16	\$6.24
12-Nov-01	\$0.20	\$0.40	\$0.61	\$2.28	\$4.56	\$6.84
13-Nov-01	\$0.18	\$0.36	\$0.54	\$2.46	\$4.93	\$7.39
14-Nov-01	\$0.14	\$0.28	\$0.42	\$2.60	\$5.20	\$7.80
15-Nov-01	\$0.16	\$0.33	\$0.49	\$2.77	\$5.53	\$8.30
16-Nov-01	\$0.17	\$0.34	\$0.52	\$2.94	\$5.88	\$8.81
17-Nov-01	\$0.18	\$0.36	\$0.55	\$3.12	\$6.24	\$9.36
18-Nov-01	\$0.13	\$0.27	\$0.40	\$3.25	\$6.51	\$9.76
19-Nov-01	\$0.15	\$0.30	\$0.46	\$3.41	\$6.81	\$10.22
20-Nov-01	\$0.17	\$0.34	\$0.51	\$3.57	\$7.15	\$10.72
21-Nov-01	\$0.18	\$0.37	\$0.55	\$3.76	\$7.52	\$11.28
22-Nov-01	\$0.10	\$0.20	\$0.29	\$3.86	\$7.71	\$11.57
23-Nov-01	\$0.12	\$0.24	\$0.36	\$3.98	\$7.95	\$11.93
24-Nov-01	\$0.08	\$0.16	\$0.24	\$4.05	\$8.11	\$12.16
25-Nov-01	\$0.00	\$0.00	\$0.00	\$4.05	\$8.11	\$12.16
26-Nov-01	\$0.12	\$0.25	\$0.37	\$4.18	\$8.36	\$12.53
27-Nov-01	\$0.07	\$0.14	\$0.21	\$4.25	\$8.50	\$12.75
28-Nov-01	\$0.10	\$0.21	\$0.31	\$4.35	\$8.70	\$13.06
29-Nov-01	\$0.00	\$0.00	\$0.00	\$4.35	\$8.70	\$13.06
30-Nov-01	\$0.00	\$0.00	\$0.00	\$4.35	\$8.70	\$13.06

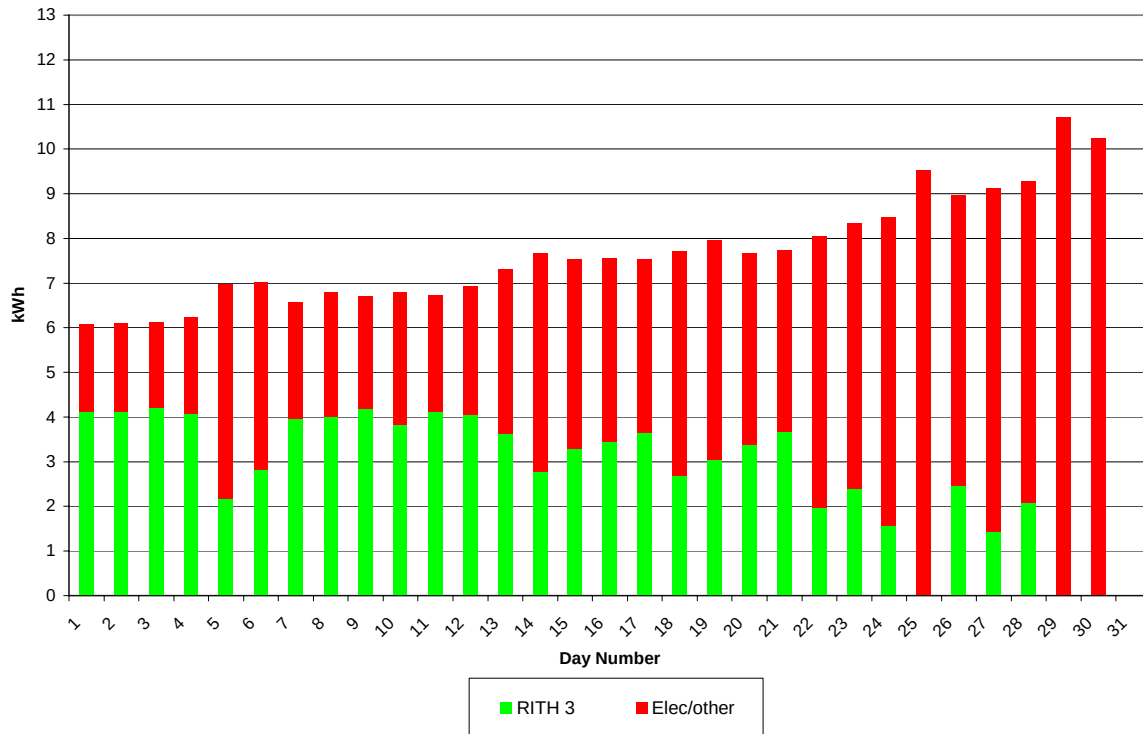
RITH 4 PERFORMANCE (November 2001)



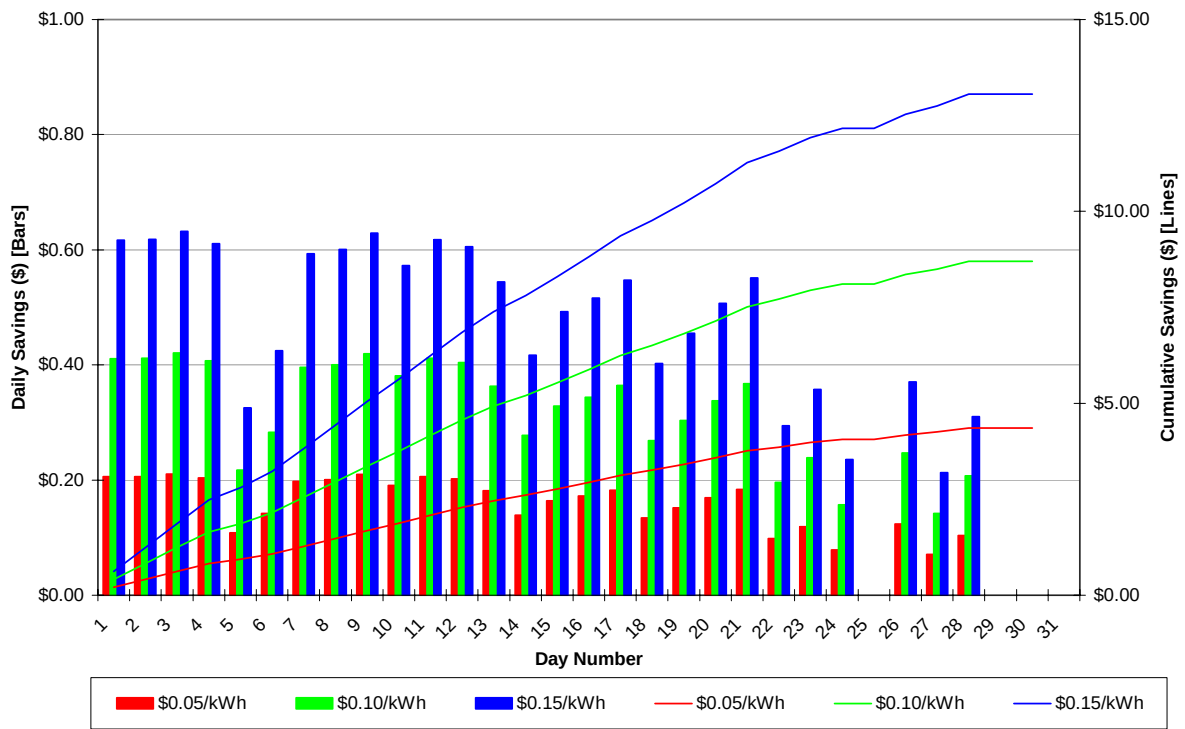
RITH 4 SOLAR FRACTION (November 2001)



RITH 4 PERFORMANCE VS TOTAL (November 2001)



RITH 4 SAVINGS AT DIFFERENT ELECTRIC RATES (November 2001)



RITH 5 TESTS

RITH 5 delivered 1,599 kWh of hot water to the home with an average sunlight-to-delivered hot water efficiency of 23% during its 12-month test period. RITH 4 delivered almost the same amount of hot water as RITH 5 even though RITH 4 operated only 8 months vs. 12 months for RITH 5. Both systems received the almost the same amount of solar energy during the three months of overlap in the testing period. Our opinion, backed by data in testing RITH 6 at the National Solar Thermal Test Facility, is the difference in efficiencies was caused by the use of flex hoses in RITH 5. The conference paper that follows was written documenting the testing of RITH 5.

ISEC2004-65153

Performance Evaluation of an Advanced Roof Integrated Solar Hot Water Heating System and Roof-Mounted Solar Photovoltaic Power System in New Home Construction

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ABSTRACT

The performance of a building integrated solar domestic water heating system and roof mounted PV system in a residential dwelling located in the Phoenix, AZ area was evaluated for a 12 month period. The solar domestic hot water heating system installed was a preproduction prototype RITH (Roof Integrated Thermosiphon) system. The RITH is a thermosiphon system that fully integrates into the roof to achieve the same profile as a skylight when seen from the street. The PV system consisted of two SAE 300 DG/50 modules, each having a 300 watt dc rating, and a GC-1000 1 kW inverter to produce 0.5 kW AC power at STC (standard temperature conditions). Both systems were installed on a Calx Homes model home in the Phoenix area on a south facing part of the roof. Both systems were mounted directly to a 5/12 pitch roof and, therefore, tilted at a 22.6° angle. Since both units were mounted on an unoccupied model home the domestic hot water (DHW) load was modeled to simulate a typical family of four living in the Phoenix area. The solar domestic water heating system was sized to meet ~70% of the annual hot water needs for a typical Phoenix family of four using 80 gallons of hot water per day. The PV system was connected directly to the grid without any battery storage and was intended to offset household electrical demand. Data

are presented for both the actual and predicted performance of the solar domestic water heating and PV systems for the 12 month monitoring period.

INTRODUCTION

Sandia National Labs (SNL), Salt River Project (SRP) and Energy Labs, Inc. (ELI) have demonstrated the reduction in electrical usage utilizing both a PV and solar domestic hot water system (DHW) installed on a typical residential house in the Phoenix area. SNL instrumented and monitored both systems. SRP is an electric utility company interested in demonstrating these systems on a house in their service area. ELI built the solar DHW system installed on the house.

Both systems were installed on a Calx Homes model home in the Phoenix area on a south facing portion of the roof. Both systems were integrated directly into the roof and, therefore, were at the same pitch as the roof, which had a 5/12 pitch or a 22.6° tilt angle. To maximize the annual output of either solar system the tilt angle should be equal to the latitude, which for Phoenix is 33.4°. Both systems were mounted directly to the roof because a SRP consumer market study found that a key attribute of any successful solar product in new home construction

should be integrated aesthetically into the roof and have the same profile as a skylight as seen from the street. An aerial view of the PV and RITH system mounted on the roof of the house in the Phoenix area is shown in figure 1. The PV modules are on the upper part of the picture and the RITH is on the lower part of the picture with north being the top of the picture. Only the RITH system has an unobstructed view of the sun. As shown in figure 1, the PV system is shadowed at some times of the year during the early morning hours from the dormer just to the east.



Figure 1: Aerial view of both systems installed on the Calnex model home in the Phoenix area. Notice the dormer causes some shading in the morning on the PV panels.

Since the model home was unoccupied during the 12 month testing period, there was no electrical load, except for the electric residential hot water heater, and the hot water usage was simulated. Models developed at SNL were used to model the performance of the PV and solar hot water systems for one year using typical meteorological year (TMY) solar data for the Phoenix area¹.

The solar domestic hot water system installed was a preproduction prototype Roof Integrated Thermosiphon (RITH) system. The RITH was developed under a CRADA (Cooperative Research And Development Agreement) between SRP and SNL. SRP lead the technology development team consisting of SNL and ELI. A RITH production unit is currently being tested by the SRCC (Solar Ratings Certification Corporation) for certification. It was intended for non-freezing climates, or wherever ICS systems are installed. The RITH concept applies a direct type thermosiphon approach to solar heat the water and eliminates the need for moving parts or valves as shown in figure 2. It uses a 70 gallon tank positioned below a 2.76 m² solar collector. All

wettable parts are stainless steel for corrosion mitigation. The solar domestic water heating system was sized to meet ~70% of the yearly hot water needs for a typical Phoenix family of four.

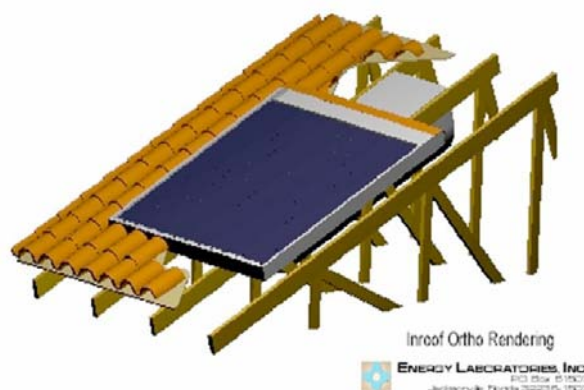


Figure 2: Artists rendering of a RITH unit integrated into a roof.

The supply water temperature into the house was measured each month of the year during 2001/2002 and is shown in table 1. With freezing water lines not a problem, the water lines are not buried very deep (code requires 12") so the water temperatures follow the ambient air temperatures more closely than in more northern areas where the water lines are buried deeper. These were the inlet water temperatures used in the model to predict the performance of the RITH unit.

Month	Inlet Water Temp. (°F)	Month	Inlet Water Temp. (°F)
January	63	July	86
February	67	August	89
March	69	September	88
April	72	October	82
May	77	November	73
June	84	December	67

Table 1: Measured residential supply water temperatures for each month in the Phoenix area.

The total DHW usage of 80 gallons/day for a typical family of four in the Phoenix area, shown in figure 3, was simulated by a bimodal distribution of hot water draws through the 24 hour daily cycle. This graph only shows the volume of water used/day, which is held constant throughout the year. The energy required to heat this water, however, will vary from month to month because the inlet temperatures (as shown in table one) vary throughout the year.

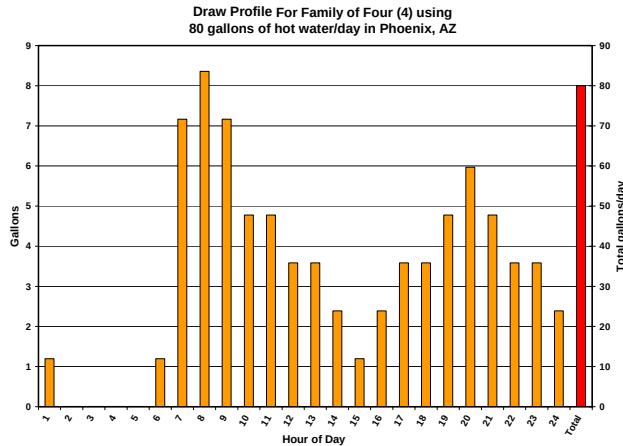


Figure 3: Plot showing the draw profile used to model the performance of the RITH

It is important to locate the solar DHW system as close as possible to the residential hot water tank. Figure 3 shows three hot water draws of 1.2 gallons, which is about 70 feet of $\frac{3}{4}$ " tubing commonly used in most housing (the type of tubing is not important since only volume is used). If more than 70 feet of tubing is used to connect the solar system to residential hot water tank than any draws of less than 1.2 gallons the hot water from the solar system will never reach the residential hot water tank. If it is 35 feet, then half of the hot water from the solar system reaches the residential hot water tank. Our experience has shown hot water in normally insulated $\frac{3}{4}$ " copper tubing reaches ambient air temperature in about 1 hour.

The inlet temperature of the hot water tank is limited throughout the year to a maximum of 49°C (120°F) through the use of a mixing valve. The RITH system can heat water above 95°C, which is too warm for personnel use. To prevent scalding a mixing valve is used to keep the inlet temperature to the hot water tank at or below 49°C (120°F).

The predicted hot water energy usage for each month is shown in figure 4, along with the predicted performance of the RITH unit. This graph shows how much more energy is required to heat the same amount of water in the winter months than the summer months because of the differences in the inlet water temperatures. This graph also shows how the RITH system produces more energy during the summer than in the winter because there is more solar energy available in the solar plane during the summer, but also because of the changes in inlet water temperatures. Comparing the RITH predicted performance to the simulated hot water load, this graph shows the RITH should heat more water than will be used during the summer months so there is

some excess energy during this time. During the winter months, however, less than 50% of the hot water needs will be supplied by the RITH due in part to its non-optimal tilt angle. The annual averages shown on the right side shows that the RITH is predicted to supply about 75% of the hot water needs on a total annual basis. This is less than the design rule-of-thumb for a solar hot water system to supply about 80% of the total annual hot water heating load, but is more than the design goal of 70%. The graph shows that to achieve more than 80% of the hot water heating load more hot water needs to be heated by the solar system during the winter months. Keeping the tilt angle the same, the only way to achieve this would be to increase the size of the collector. The current collector size already has excess energy during the summer months, so a larger collector would contribute to storage tank overheating, which is a safety and durability issue. It also would not be very cost effective.

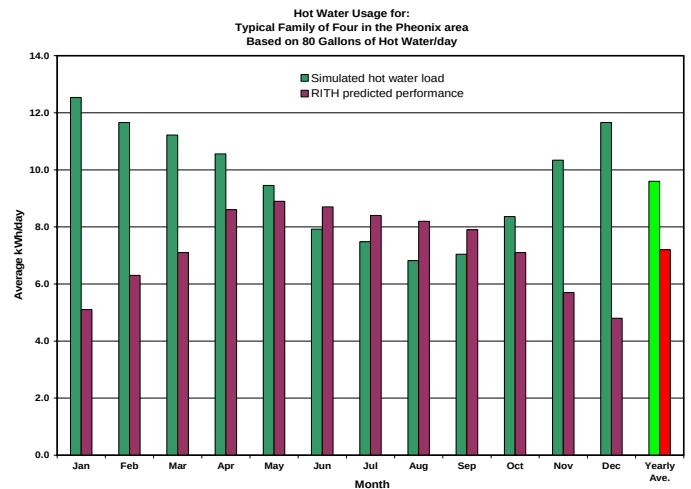


Figure 4: Plot showing the predicted hot water energy usage and RITH performance for each month of the year. The two bars on the right show the yearly averages.

The biggest difference between the RITH and the PV system is the storage. The RITH generates hot water, stores it in the 70 gallon tank and delivers it when it is needed. The PV system, by design, has no battery storage to supply energy when the sun is not shining or when the grid goes down. Both systems will reduce the electrical load of the house. The PV system will do it directly since it is tied to the grid. The RITH will lower it indirectly because it is assumed the hot water heater in the house is an electric one.

The model for the RITH system is a simple model. It multiplies the incoming solar radiation times the area of the solar collector times the estimated system

efficiency of 40% to determine the amount of energy available to heat water. The estimated system efficiency of 40% was derived from testing of earlier prototype systems at SNL. Both the PV and solar DHW models used the typical meteorological year (TMY) data derived from the 1961-1990 National Solar Radiation Data Base (NSRDB) for Phoenix, AZ¹. The PV model also used the average air temperatures from the TMY data.

There are three aspects that apply to all solar DHW systems not taken into account in this simple model for the solar DHW system. First, excess hot water generated by the RITH is not carried over to the next day, as it would be in real life. Second, since a check valve is not used between the collector and the storage tank in the solar system a reverse thermosiphon flow will occur during the night. The magnitude of the reverse thermo flow losses is based on the collector configuration relative to the tank, the roof angle, and the temperature gradient in the storage tank. The effect of this will be to lower the water temperature in the tank during the night as the hot water in the tank is circulated through the cooler collector at night. The colder the night the higher the heat losses will be since thermosiphon flow is determined by water temperature difference between the tank and the solar collector. This also gives it a small amount of freeze protection because there is some flow through the collector at night. The third reason, normal heat losses from the tank through the insulation was not taken into account because for the Phoenix area these losses are considered small.

The residential PV system installed employed two ASE 300 DG/50 modules with a 300 watt dc rating, and a GC-1000 1 kW inverter. The modules use crystalline silicon cells. Each module has a power rating of 285 watts at STC (an irradiance level of 1000 W/m² and cell temperature at 25°C). The PV system was connected directly to the grid without battery storage and was intended to offset the household electrical bill by reducing the net metered demand.

The model used to estimate the performance of the PV system was developed at Sandia. The model takes into account the tilt of the arrays and the average air temperatures expected in the Phoenix area because PV system efficiency decreases as ambient air temperature increases. A detailed description of this model is given in reference (2) so it will not be given in this paper. The actual output of the PV system was compared to this model to gauge the performance of the PV system.

Figure 5 shows the predicted AC output of the PV array for July 15. Since the PV system does not have storage and if it produces more power than is being used the excess energy of the PV system is not wasted. This is not the case because this excess power is put onto the power grid so the meter on the house turns backwards.

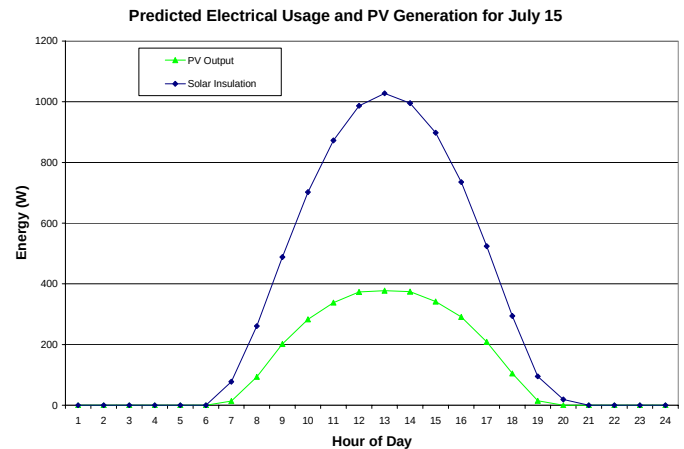


Figure 5: Plot showing the model's prediction for solar insolation and PV output for a typical July 15.

This paper considers the output for both the PV and solar DHW systems to be independent of the electric rate being applied. In other words, having one or both of these systems will not change which electric rate plan will be used. These systems are only dependant on the outdoor weather conditions.

Results

The monitoring of both systems started April 12, 2004 and ended April 16, 2003. Both systems operated problem free throughout the test period. There was, however, a power outage on February 20, 2003 caused by a lightning strike causing erratic operation on the data acquisition system (DAS). On February 25 the DAS was reset and it operated smoothly since. The erratic operation of the DAS caused excess hot water usage between February 20 and 25. On February 12 a breaker for the PV system tripped, disconnecting it from the grid and it remained off line from the grid until April 3, 2003.

The DHW results will be shown first. On a good solar day the RITH system produced about 7.5 kWh of hot water. Testing at SNL on another prototype had shown the nightly reverse thermosiphon losses to be about 1.7 kWh for a typical spring day in Albuquerque, NM, which is about 20 to 25% of the

heat gain during the day. These losses naturally will be lower in the summer and higher in the winter months. These losses, overall, will also be lower in the Phoenix area since the temperatures there are higher overall than in Albuquerque. The RITH system averaged 4.0 kWh/day of DHW during the 12 month test period. During the summer it averaged about 5.0 kWh/day and during the winter it averaged about 2.6 kWh/day. For the 12 month test period it produced 1,460 kWh.

Figure 6 shows the actual and predicted DHW load the RITH is supplying for the home in terms of a percentage for the 12 month testing period. Notice the power outage in February did lower the amount of hot water supplied by the RITH but it was not significant. The predicted amount of DHW being supplied by the RITH was based on the radiation insolation from the TMY data. The right side shows the 12 month averages. It was predicted to supply 75% of the annual DHW load and the actual amount was 72%.

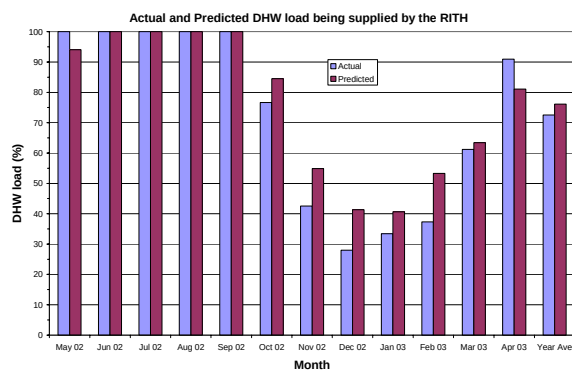


Figure 6: Plot showing the actual and predicted DHW load supplied by the RITH system for the 12 month testing period.

Figure 7 shows actual output of the PV array during a clear day in July along with the solar insolation. Comparing this graph with the predicted output shown in figure 5 shows the effect the shadow from the dormer had on the output of the PV array. The day was cloud free, as can be seen by the solar insolation curve, but the output of the PV system is suppressed until about 10 o'clock when it fully emerged from the dormer's shadow.

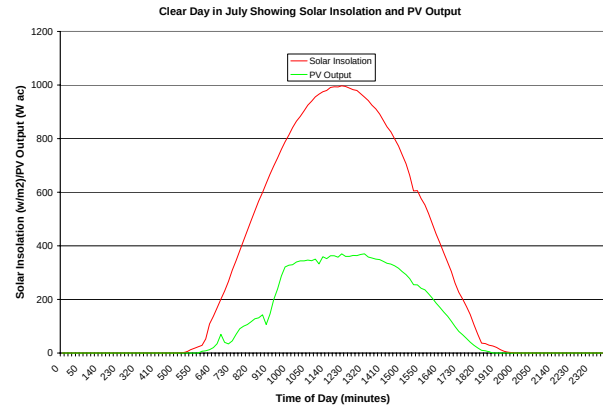


Figure 7: Plot showing the effect of the shadow from the dormer on the output of the PV array.

The actual output of the PV array compared to the predicted output is shown in figure 8. Notice the lack of data for March and the significant decrease in power output for February and April 2002 and 2003. The April data reflect starting the test in the middle of the month so these were not complete months. The February and March data reflect the power outage in February. The two bars on the right side of figure 8 shows the total output of the array compared to the predicted output. During the test period, the PV system generated 696 kWh ac and the model predicted a total of 845 kWh ac, taking into account only when the PV system was operational as explained earlier. The PV system, therefore, produced 82% of what it was predicted to generate. The average solar insolation during the test period was about 3% lower than the TMY data prediction, which the model uses. The difference between the actual and predicted output of the PV array can be attributed to the affect of the shadow caused by the dormer.

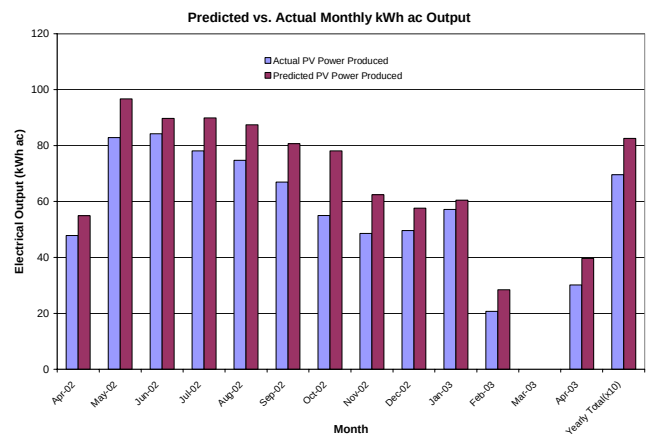


Figure 8: Plot showing the output of the PV array as a percentage of predicted output.

Conclusion

The model used to predict the performance of the RITH agreed very well with actual usage. Based on 80 gallons/day of hot water usage, the model predicted the RITH would supply 75% of the yearly DHW needs. During the 12 month test period it actually delivered 72% of the hot water load, or 1,440 kWh. These numbers will be different for every household because the amount of hot water used varies from household to household.

The model used to predict the performance of the PV panels agreed closely with actual data, except for the affect of the shadow from the dormer. The model predicts, and the actual data supports, a reduction in electrical usage for this typical household using this PV system to be around 950 kWh/year, assuming no interruption of the arrays output and no shading.

Both systems operated trouble free, except for tripped breakers from a lightening strike, and the models prediction were accurate. Using both systems would significantly reduce energy consumption for most households in the Phoenix area. This paper did

not cover actual cost savings for either system due to fluctuations in energy costs.

ACKNOWLEDGMENTS

We would like to thank Dave Menicucci for his hours of guidance and instruction.

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REFERENCES

(1) Marion, W., and Wilcox, S., Solar Radiation Data Manual for Flat-Plat and Concentrating Collectors, NREL, Golden, CO, 1994

(2) D. L. King, W. E. Boyson, J. A. Kratochvil, "Analysis of Factors Influencing the Annual Energy Production of Photovoltaic Systems", 29th IEEE PVSC, May, 2002, New Orleans, SAND 2002-1672C

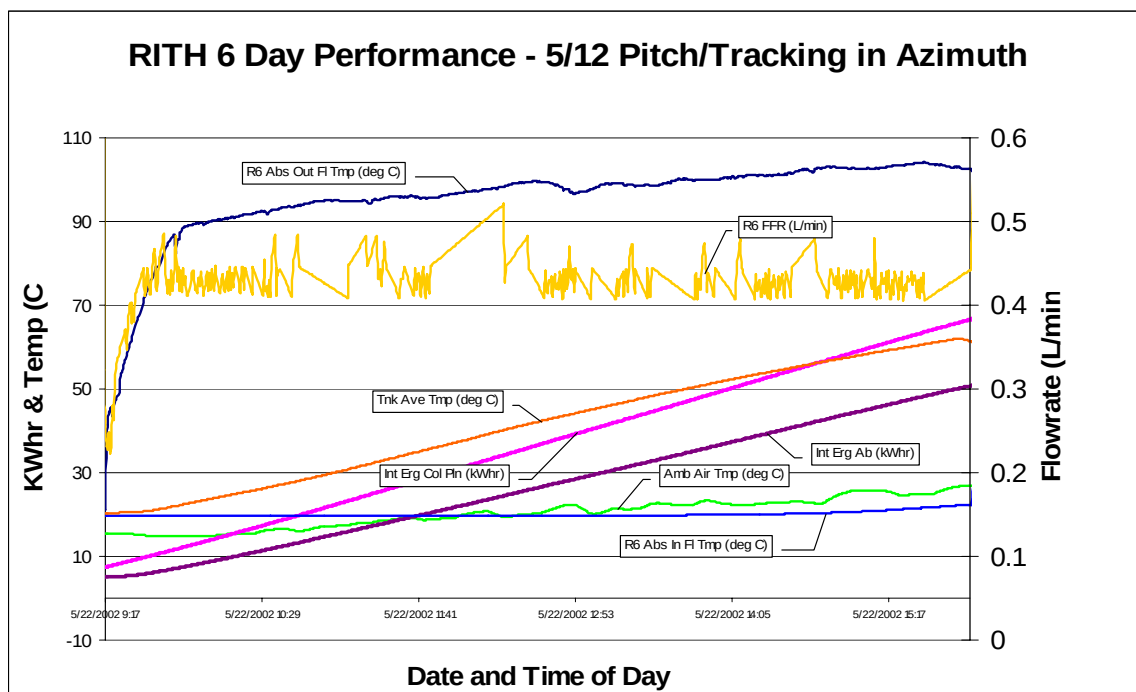
Appendix I.

Test Results of RITH 6

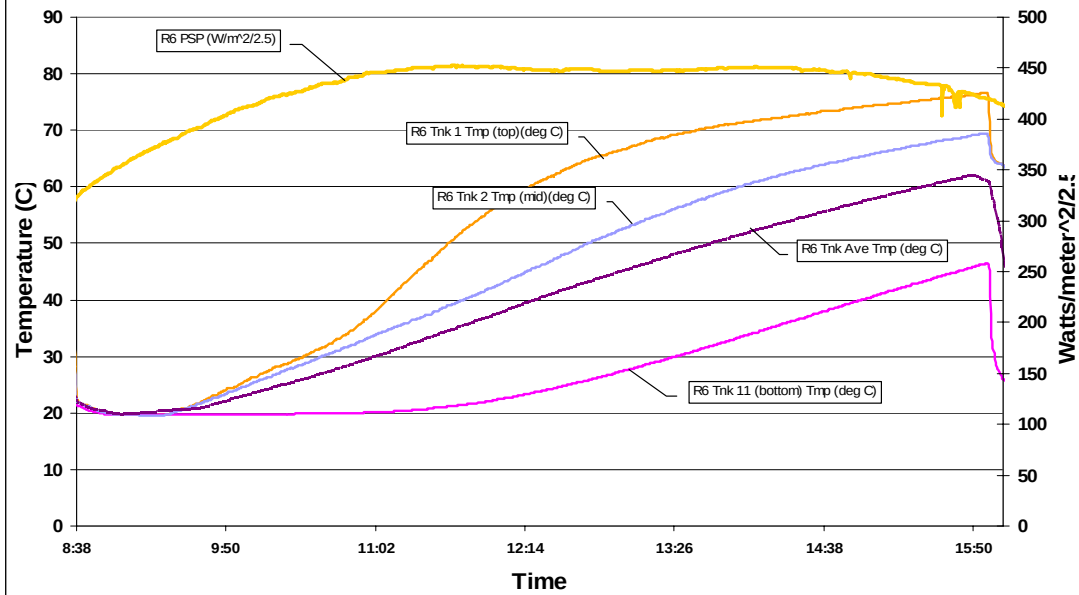
RITH 6 was tested on the rotating platform for about one year, from January 2002 to January 2003. The testing started out with a collector using copper tubing. On July 11, 2002, the collector was replaced with an identically sized collector but it used stainless steel tubing. At the start of testing there was a leak at the joint from the collector outlet to the flex hose going to the storage tank. To fix the leak the flex hose was replaced with a piece of bendable stainless steel tubing.

The average efficiency over many days of testing for RITH 6 when tracking the sun at a 5/12 pitch using the copper collector was 76.4%. The average efficiency of RITH 6 using the stainless steel collector was 68.7%.

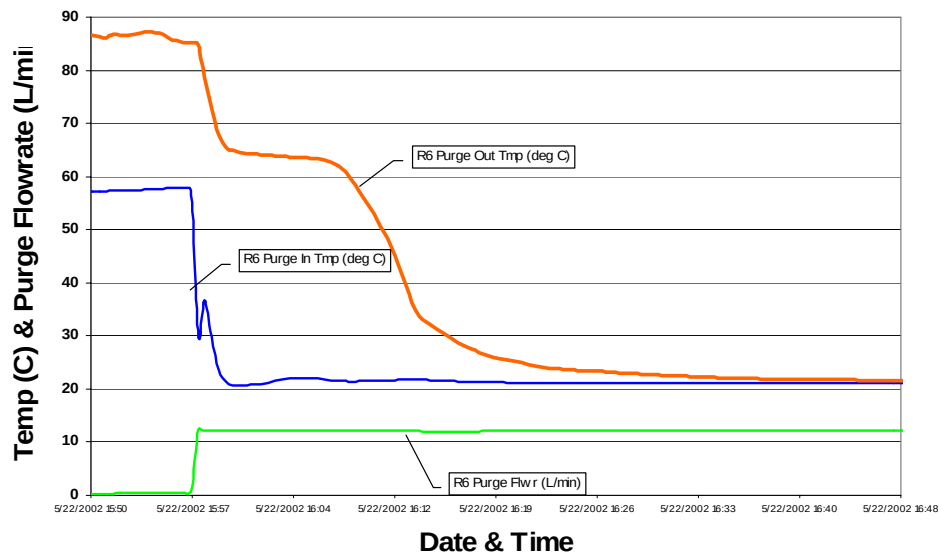
Outlined below are plots showing the performance of the RITH 6 system.

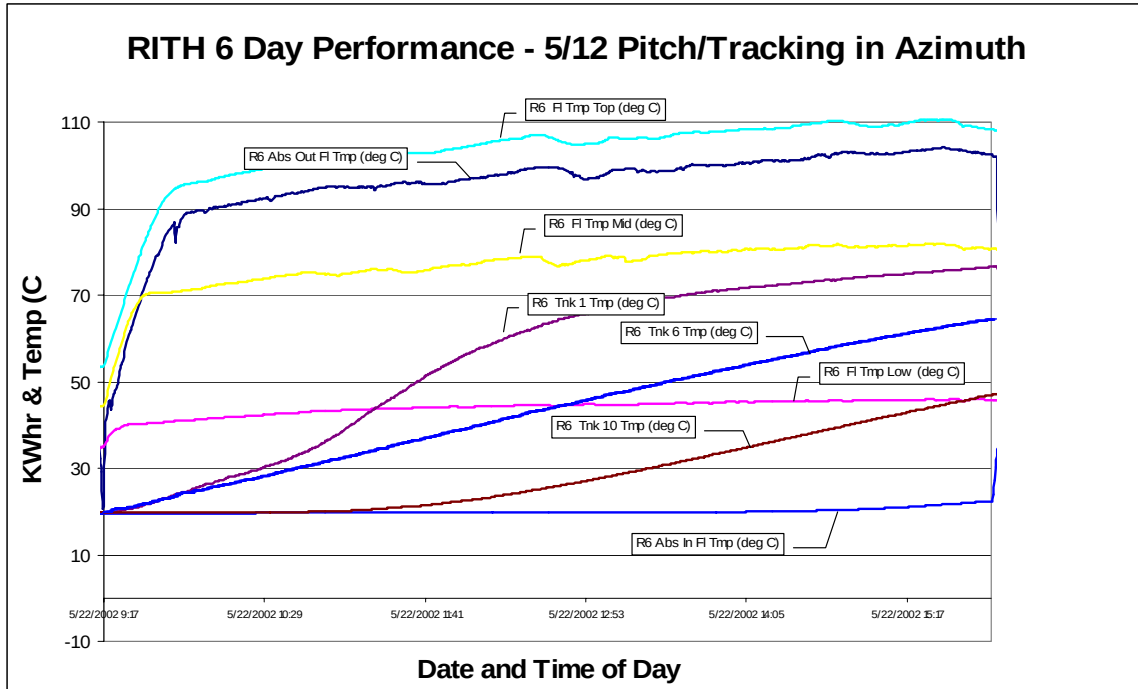


RITH 6 Thermocline @ 5/12 Pitch-Tracking in Azimuth



RITH 6 End of Day Purge

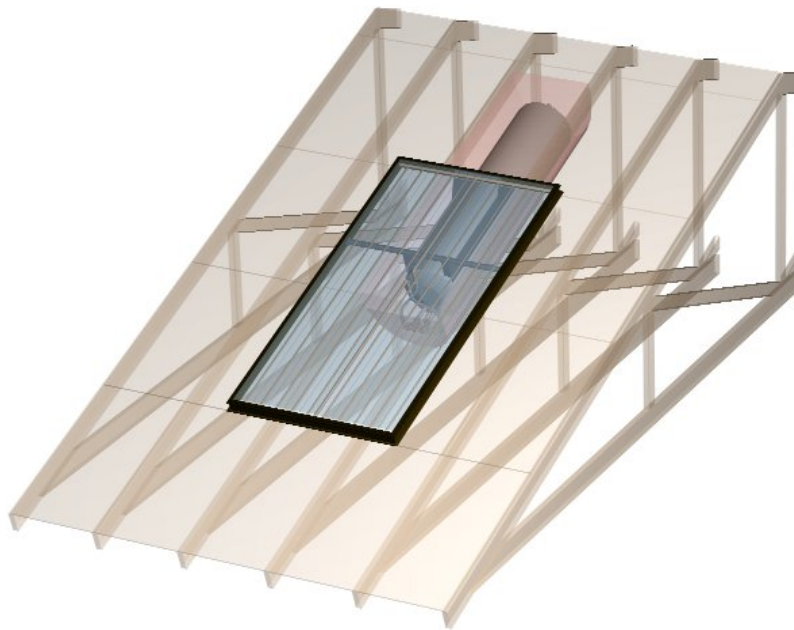




Appendix J.

Manufacturing Analysis

RITH SYSTEM MANUFACTURING PROCESS FLOW OUTLINE



By:



ENERGY LABORATORIES, INC.

The current RITH System configuration has three main components making up the finished product. They are

- the collector assembly,
- the tank assembly, and
- the packaging.

Each of these has subassemblies requiring individual manufacturing or assembly processes to create them. The process flow shown here in outline form shows only the steps required to produce a system. Time lines, labor allocations, and inventory management procedures are also required as part of a complete manufacturing process.

THE COLLECTOR ASSEMBLY

Absorber

Header Fabrication (Equipment: Cutters, T-drill, de-burring tool)

- (1) 1) Length Cutting
- 2) T-drilling
- 3) Cleaning and de-burring
- 4) Stage

Fin-Tube Fabrication (Equipment: Cutters, snips, tables, laser welder)

- 1) Cut tubes to length
- 2) Stage
- 3) Cut fin material to length
- 4) Stage
- 5) Laser weld fins to tubes
- 6) Stage fin tube assemblies

Brazing (Equipment: Brazing station, dual torch, table)

- 1) Header setup (insert end caps and exit/entry tubes)
- 2) Fin-tube setup
- 3) Braze complete absorber assembly
- 4) Inspect
- 4) Repair as required
- 6) Clean up joints
- 7) Stage

Pressure Checking (Equipment: Immersion table)

- 1) Absorber assembly setup
- 2) Test
 - a. Accept
 - b. Reject
- 3) Stage absorber assemblies for collector final assembly

Header Cover Fabrication (Equipment: Shear, Auto Break)

- 1) Cut fin material to length
- 2) Configure auto break for regular folding
- 3) Fold on auto break
- 4) Stage

Housing

Collector Box Punching (Equipment: Press break, Uni-tool punches, parts cart)

- 1) Using press break and punches, punch box material corners and header outlets
- 2) Transfer parts to cart
- 3) Stage parts at auto break

Collector Box Forming

- 1) Configure auto break for box forming
- 2) Insert box material into auto break
- 3) Run side forming program
- 4) Run end forming program
- 5) Stage parts for box building

Batten Punching (Equipment: Shear, uncoiler, press break, Uni-tool punches)

- 1) Uncoil and shear battens to length
- 2) Pass to press break station
- 3) Punch battens
- 4) Stage parts at auto break

Batten Forming (Equipment: Auto break)

- 1) Re-configure auto break for regular folding
- 2) Insert batten
- 3) Run folding program
- 4) Stage parts to collector final assembly

Box Building (Equipment: Collector assembly table, air tools, TIG welder)

- 1) Assemble frame extrusions into outer housing
- 2) Square and secure
- 3) Insert back-sheet
- 4) Stage housings

Insulate Collector Housing (Equipment: Gusmer foam machine, mold, uncoiler for release sheet, air supply manifold)

- 1) Insert housing into mold station
- 2) Inject liquid foam
- 3) Pull barrier layer into position
- 4) Trim
- 5) Close mold cover
- 6) Allow rise time
- 7) Release cover
- 8) Remove housing
- 9) Trim excess
- 10) Stage for final assembly

Final Assembly (Equipment: Tables, air tools, cleaning supplies)

- 1) Insert completed absorber assembly
- 2) Insert header covers
- 3) Install through wall gasket
- 4) Install gasket on glass
- 5) Install glass with gasket on housing
- 6) Secure glazing battens with screws
- 7) Install collector to tank union
- 8) Apply Solar Rating and Certification Corporation (SRCC) labels
- 9) Clean outside
- 10) Move to packaging

This completes the collector assembly process flow steps. On a parallel path the tank assembly is being produced. In addition to the operations shown below, support operations for making vacuum formed parts, staging consumables, staging raw materials and fittings, and producing jackets are taking place.

THE TANK ASSEMBLY

Stainless Steel Tank

Head Fabrication (Equipment: Press, punch dies, marker template)

- 1) Inspect drawn heads
- 2) Stage heads for punching
- 3) Mark heads
- 4) Punch
- 5) Insert fittings
- 6) Weld fittings
- 7) Stage

Tank Body Fabrication (Equipment: Plate bending rolls, seam welder, transfer carts)

- 1) Inspect stainless steel blanks
- 2) Stage for rolling
- 3) Roll tank bodies
- 4) Stage for welding
- 5) Seam weld bodies
- 6) Inspect
- 7) Stage for assembly

Complete Tank Assembly (Equipment: Head-to-body clamps, spot TIG welder, turning rolls, high-power TIG welder, welding lathe, plasma welder for seams)

- 1) Move tank body to head weld station
- 2) Using head-to-body clamps, tack weld heads to body
- 3) Stage for full head welding
- 4) Weld heads using rotating station
- 5) Re-do seam weld where it meets the heads
- 6) Inspect
- 7) Stage

Tank Mounts

Shear 60 x 120 sheets to sizes for CNC punching (Equipment: Shear)

- 1) Stage material at shear
- 2) Use cut list to produce required sizes
- 3) Shear material
- 4) Stage

CNC Punching (Equipment: Amada CNC punch, computer, modem line, hand tools, calipers and micrometers, table)

- 1) Pull-up program
- 2) Run trial program
- 3) Insert material
- 4) Run parts
- 5) Inspect first article
- 6) Adjust
- 7) Run all parts
- 8) Stage



CNC operations require significant parts engineering, programming and machine maintenance.

Metal Bending (Equipment: Press break, dies, calipers, hand tools)

- 1) Setup press break
- 2) Bend first article
- 3) Inspect
- 4) Adjust as required
- 5) Run parts
- 6) Stage

Mount Welding (Equipment: Welding jig, TIG welder)

- 1) Assemble parts on jig
- 2) Weld first article
- 3) Check for distortion
- 4) Adjust
- 5) Run parts
- 6) Stage

Mate Mounts to Tanks (Equipment: Assembly jig, TIG welder)

- 1) Set completed tank assembly in jig
- 2) Affix mount assembly to tank in jig
- 3) Tack weld tank mount and tank together
- 4) Inspect for alignment
- 5) Weld
- 6) Stage

Final Assembly Steps

Air Eliminator Fabrication (Equipment: Copper tube tools, brazing station jig, brazing torch, air pressure checking tools)

- 1) Using shop drawing, cut tubes
- 2) Assemble tubes per drawing
- 3) Attach Teflon tube fittings

- 4) Install Teflon tubing
- 5) Pressure check
- 6) Accept or reject
- 7) Stage

Attach Air Eliminator (Equipment: Assembly stand, brazing torch, hand tools)

- 1) Set tank in stand
- 2) Attach air eliminator assembly
- 3) Attach air eliminator Teflon tubing to collector interconnect fittings
- 4) Stage

Pressure Check (Equip: Pressure checking station, manifold, air lines, water lines, pressure meter, magnifying glass)

- 1) Set completed tank with mounts assembly in pressure checking jig
- 2) Affix pressure checking manifold
- 3) Fill tank with line pressure water
- 4) Attach air line to manifold
- 5) Pressurize to 125 psi
- 6) Check for leaks
 - a. Accept – Stage for Jacket and Insulation
 - b. Reject – Send assembly back to welding with leaks noted
- 7) Re-test repaired tanks
- 8) Stage

Jacket and Insulate Tanks (Equipment: Insulation station, Gusmer foam machine, assembly table, storage racks, carts, hand tools)

- 1) Set preformed aluminum jacket in insulating jig
- 2) Set tank assembly with mounts attached inside jacket
- 3) Attach vacuum formed spacers
- 4) Check for alignment
- 5) Insulate
- 6) Wait for cooling
- 7) Remove tank form jig
- 8) Attach vacuum formed end caps
- 9) Stage for packaging

While collectors and tanks are being produced, packaging is being acquired and staged for completion of the entire process.

PACKAGING

(Equipment required for these operations consist of tables, air tools, and hand tools)

Assemble Tank Box

- 1) Using preformed corrugated parts assemble outer shell
- 2) Insert cushioned spacers and standoffs
- 3) Stage

Insert tanks

- 1) Place tank in preformed box
- 2) Insert top spacers and cushions
- 3) Insert literature
- 4) Close box
- 5) Staple
- 6) Strap
- 7) Palletize and store for shipping

Assemble Collector Box

- 1) Using preformed corrugated parts assemble outer shell
- 2) Insert spacers
- 3) Insert literature
- 4) Stage

Insert Collectors

- 1) Place collectors in boxes
- 2) Install spacers
- 3) Close
- 4) Staple
- 5) Strap
- 6) Palletize for shipping

Assemble Flashings and Accessories Box

- 1) Using preformed parts, assemble shell
- 2) Install spacers
- 3) Insert literature
- 4) Stage

Insert Flashings and Accessories

- 1) Insert flashings and accessories
- 2) Close
- 3) Stable
- 4) Palletize for shipping

This concludes the process flow outline for RITH systems.

As referenced above, support operations would be taking place as the major components are being produced and assembled. These are:

- Vacuum forming
- Small parts fabrication
- Tank jacket production (main use of the auto break)
- Flashing fabrication
- Parts assembly and bagging for accessories
- Literature production
- Label production
- Glass cleaning and staging
- Raw materials staging
- Purchasing
- Inventory management
- Quality assurance testing
- Order processing
- Equipment maintenance

Details of the support operations process flow can be provided as a component of a detailed process flow analysis where multiple time lines and co-dependent operations can be shown.

A complete detailed process flow analysis showing time lines, labor burdens, and required overhead components can be provided under contract. Analysis would include detailed process flow outlines being converted to charts and presentation format using Microsoft Excel, Microsoft Project, and Microsoft PowerPoint. Scope of the package would include all corporate functions required to produce, market, sell, and deliver RITH units to the market.

Projected time to complete would be 45 days. Estimated cost for complete package provided by request.

Manufacturing Analysis of the ELI Interroof Solar Hot Water System



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Manufacturing Analysis of the Interroof Solar Collector System

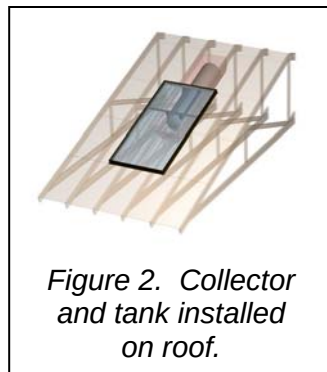
Introduction and Summary

This report is a manufacturing analysis of the Interroof solar collector for residential domestic hot water. The system was designed jointly by Energy Laboratories, Inc. (ELI), the Arizona Salt River Project, and Sandia National Laboratories. It is a roof-mounted flat-plate collector with an integrated 75-gallon storage tank. The unit passively circulates water by thermosiphon. This feature eliminates the need for any circulation pumps to feed water through the collector. The collector system is designed to be mounted between roofing trusses. It is used in conjunction with a conventional hot water heater so that hot water is provided under all solar conditions.

Although the collector system could be installed in an existing structure, it is aimed at new construction because of the substantial roof penetration needed. All the pipes and tanks in the system are made of stainless steel, a feature necessary because the water chemistry in some parts of Arizona can be hostile to copper plumbing. There is no freeze protection designed into the system because the target market in Arizona does not warrant any.

The details of the engineering design have changed in minor ways through construction of several prototypes. These prototypes have been tested at Sandia and in Arizona.

ELI has experience building all the components of this system except for laser welding copper fins to the stainless steel absorber tubes. This welding process was developed at Sandia



and all prototypes built were welded at Sandia. ELI has built all the remaining components at their factory and has manufactured similar items for other customers in Florida and elsewhere. They were involved with the design of the interroof system and believe that the design is manufacturable with the equipment they have in place. They have a 14,500-square-foot facility equipped with most of the manufacturing equipment and personnel needed to produce all components of the Interroof system.

The purpose of this study is to review the manufacturing processes needed and come up with independent estimates for what the recurring production costs would be for this system if it were produced at rates of 1000 or 3000 units per year. Possible improvements to the production processes will be noted and their effect on costs estimated. Startup costs, time, and necessary equipment and/or capabilities needed to begin the production are estimated and listed.



We conclude that ELI's existing physical plant has the equipment and floor space to accommodate either the 1000 and 3000 unit per year rate, though the higher rate may require multiple production shifts. ELI solar prototype projects currently occupying the facility may have to be consolidated or offloaded to another building for either production scenario. ELI is aware of this issue, and is prepared to lease additional space if necessary. The basic manufacturing processes used by ELI for prototypes would no doubt need to be adjusted and improved for both sustained production scenarios. These adjustments could include outsourcing of some subassemblies, development of more durable tooling, and replacement of some older pieces of equipment. But we believe the production methods would still be similar to those used for ELI's prototype program.

The principal startup issues involve consolidating other smaller projects in the plant; rearranging floor space; hiring and training production personnel; installing and debugging the laser welding system; and creating and implementing some basic production quality assurance (QA) techniques and controls. ELI believes that the production could be commenced within six months. Our estimate of the startup costs indicate that these costs could be recovered within two years if there is a sustainable market for either production level at the estimated delivered price.

Our estimates of a delivered unit price including plant overhead, labor, materials, profit, recovery of startup costs and shipping are \$2090 (1000 units/yr) and \$1674 (3000 units/yr) delivered to a warehouse in Arizona. Our estimate of installed costs on site including loaded installer labor and appliance costs markups would be \$2633 (1000 units/yr) and \$2155 at 3000 units/year. These figures are summarized in tables included in this report. Separate spreadsheets are also available that show how specifics were calculated.

A few comments about these estimates are relevant. Approximately 70% of the manufacturing cost of the system is in raw materials. These materials (stainless steel, aluminum, glass, etc.) are commodities and substantial changes in their prices are unlikely in the near term. The remaining labor costs are based on estimates gathered from examining processes or from experience in building prototypes. Production labor hours can be expected to fall with time, based on the increasing skill of the assembly workers and through evolving improvements in the manufacturing processes. We have not attempted to account for this "learning curve" effect, partly because of the relatively small labor component in the total costs.

Description of Energy Laboratories, Inc.

ELI is a small business that has been building solar equipment in Jacksonville, Florida, for the last ten years. Technically, ELI is actually two companies operating under the same roof, ELI and SEI (Solar Energy Inc.). ELI is focused on developing prototype systems while SEI is the production arm. For the purposes of this report, we will refer to just a single entity, ELI, with the understanding that production is actually the responsibility of SEI.

ELI has worked for the last five years on the Interroof system. It has been supported by contracts from Sandia and the State of Arizona Salt River Project. Most of the prototype Interroof hardware has been produced at the ELI plant, giving ELI a very intimate knowledge about this system – and an opportunity to influence the design to fit with its manufacturing processes.

The 14,500-square-foot facility that ELI leases is primarily non air conditioned high-bay style factory floor space. There is a loading dock access for large trucks for shipping and receiving. There are approximately 1000 square feet of air conditioned office, conference, and reception areas.

We have estimated ELI's overhead costs for factory floor space, utilities, administrative and secretarial staff, and equipment leases at about \$32,000/month. We have itemized the major cost elements (Table 1) of ELI's overhead and assume that the overhead would be the same for production of 1000 or 3000 Interroof units per year. ELI currently employs about 10 factory workers at a cost (including benefits) of about \$18/hour. Its staff is similar in skill and labor cost to the type of labor needed for production of this system.

Table 1. Overhead estimate for ELI production operations.

Office/Factory rent:	\$5438	Florida lease rates, \$4.50/sq. ft./year
Utilities:	\$2000	Estimate, factory has relatively low energy intensity
Receptionist/secy/admin. Asst.:	\$3000	Salary plus benefits, \$36K/year
CEO/manager/personnel/sales:	\$10000	Salary plus benefits, \$120K/year. CEO could be shared with prototype company.
Production/QA/Sales engineer:	\$7000	Salary plus benefits, \$84K/year
Accountant:	\$800	10 hours/month at \$80/hour
Legal:	\$1000	5 hours/month at \$200/hour
Manufacturing equipment depreciation:	\$2398	Based on \$274K capital equipment value, 10-year life, 10% financing fees
Office computers, copiers, printers, etc.:	\$210	Based on \$12K initial value, 5-year life, 10% financing fees
Total:	\$31,845	

All the capital equipment needed (shears, welders, brakes, vacuum formers, etc.) to produce the Interroof system is on the factory floor. Most of the equipment is in good condition. The major items needed to produce this system are listed in Table 2. Some of the equipment on the floor is owned by Sandia and will remain available for production if needed. The remainder is under lease by ELI and these leasing costs are included in their plant overhead.

We looked at all the production equipment in the plant except the laser welder owned by Sandia. This item is critical for welding the stainless steel/copper tube and fin absorber component. Sandia produced these components for the prototypes, so ELI will need to install this machine and learn how to use it in production. Today, the machine remains in crates at ELI.

Only items worth over \$10K are included in Table 2 and pictured in Figures 3 through 6, but ELI has many smaller items that are needed for production. All the equipment needed for production has a replacement value of around \$500K.



Figure 3. Pico roll former.



Figure 4. Schechtel CNC brake.



Figure 5. Jetline seam welder.



Figure 6. Gusmer foam generator.

In addition to this equipment, a few pieces of hard tooling were created specifically for manufacturing the Interroof system. These include fixtures for holding tank and collector parts for the foaming operations and several patterns for vacuum-formed components. This tooling should be adequate for supporting years of production.

ELI's staff is skilled, enthusiastic, and comfortable with operating the sophisticated machinery in the plant. They are fully capable of building the Interroof system as designed. However, there is no formal QA system in place. Bringing a sustained production process to the plant would require a few QA basics to be implemented. These include written and controlled drawing sets, purchased product specifications, manufacturing process instructions, inspection procedures, shipping checklists, and employee training programs. These controls help ensure that production quality and traceability is maintained through staff turnover, design changes, supplier changes, etc.

The ELI plant currently has projects and customers producing annual sales around \$850K. The production of Interroof systems at either a 1000 or 3000 unit annual rate would be a substantial increase in ELI's normal sales. We estimate that ten full-time production employees would be needed to produce 1000 units per year. Three thousand units could probably be built with 20 additional employees. Either production scenario would require hiring and training new production staff.

Table 2. Plant equipment for Interroof production.

Machine	Purpose	Brand, Estimated Replacement Value
Roll former	Form tank cylinder, aluminum shroud	AMB Pico, \$35K
CNC punch	Punch tank, hanger, collector components	Amada, \$35K
CNC brake	Form collector housing, flashings, etc.	Schechtel, \$50K, owned by SNL
Seam welder	Plasma weld tank cylinder	Jet Line, \$70K
Plasma welding equipment	Longitudinal and circumferential weld on tank	Jet Line PMA 4, \$36K
Sheet metal shear	Cutting parts for tank, collector, etc.	Wysong, \$10K
Vacuum former	Tank ends, spacers between tank and shroud, roof flashing	Brand unknown, \$10K
Laser welder	Welds copper fins to stainless steel tubing in collector	Brand unknown, \$200K, owned by SNL
Foam machine	Insulation for collector, tank	Gusmer, \$20K, owned by SNL

We do not anticipate a major problem with this if the production rate is allowed to ramp up over a time (six months, for example). ELI has a core of trained workers who can help train new ones while participating in the manufacturing process, provided the production demands are not too strong initially. Table 3 summarizes our estimate of the startup costs for this enterprise. (The table shows the elements that were cost-estimated, but the numbers are not included here because they are proprietary.)

Table 3. Estimated startup costs for ELI.

Production Quantity, per year	1000	3000
6 months ramp-up, production labor, \$/hr		
6 months factory overhead		
.25 FTE QA consultant, \$/hr		
Production mods for plant		
Materials costs, 62 and 187 prototype starts		
Revenue, 50 and 150 unit sales (% scrap of prototypes)		
Total:		

Manufacturing Processes

These processes are described only to the extent needed to make a reasonable estimate of manufacturing time and material costs. Since actual production has not commenced, ELI will undoubtedly change some of the details based on production realities.

Absorber Assembly: Tap water enters and leaves the 46 in. × 96 in. flat plate collector through the absorber assembly. It consists of two 1-in. stainless steel header tubes connected in parallel with 10 5/8-in. stainless absorber tubes. The absorber tubes are faced with 4-in. wide copper fins with a “black crystal” absorbent coating. These fins are oriented parallel to the plane of the collector. They are attached to the absorber tubes with an automated laser welding process developed by Sandia. This process ensures tight thermal and physical contact of the fin with the tube. The combined fins and tubes are brazed to the 1-in. header that has been manually drilled. This completed subassembly is immersed in water and visually leak tested by pressurizing with air.



Figure 7. Typical absorber assembly.

Collector Assembly: This consists of an aluminum base pan, foam insulation in the bottom of the pan, the absorber assembly, and a clear glass cover with associated gaskets and sealing hardware. The base pan is pre-cut and punched from .032-in.-thick 3003 H14 aluminum sheet using a shear and CNC punch. A CNC brake forms the four sides and corner pieces that are secured by sheet metal screws and pop rivets. The bottom of the pan is filled with 3-in.-deep polyurethane foam insulation, injected while the pan is supported in a foaming jig. The absorber assembly rests inside the pan on top of the foam and is supported by various brackets and supports. Supply and return stainless steel piping to the absorber headers is routed through pre-cut holes in the base pan. Sealants and gaskets are applied to the top of the base pan before placing the glass cover. The outside of the glass cover is secured with brake-formed bright stainless steel batons that are coated with sealant and secured to the base pan with sheet metal screws.

Stainless Steel Tank: The 75-gallon stainless steel tank attached to the Interroof system is made entirely from 16 gage 316 stainless steel. The cylindrical part of the tank is made at ELI from purchased sheets that are rolled into a cylinder and seam welded axially with an automated plasma welder. The end caps are stampings made by a local supplier. ELI has purchased quite a few of these stampings for various tank projects and so the die costs have been amortized over a significant number of units delivered. ELI punches holes in the end caps and the cylindrical tank section. Four stainless steel pipe threaded couplings are hand-welded into these holes. These threaded connections are used



Figure 8. ELI stainless steel tanks.

for field connecting the house plumbing and the collector assembly into the tank. The end caps are then tack-welded manually to the cylindrical sections. The continuous circumferential welds are then completed with an automated TIG welder tool that rolls the tank past a welding head. The tank is then inspected and any poor welds are touched up manually if needed. A simple pressurized water leak test of the tank is performed before adding foam insulation.



Figure 9. Wood patterns for vacuum-formed parts.

The tank is insulated with a 2-in.-thick layer of polyurethane foam. The foam is contained between the tank and an external cylindrical sheath of .025-in. bright aluminum sheet. The aluminum sheet is roll formed or made on a CNC brake into a cylindrical shape and riveted along the axial seam. The tank and aluminum sheath is placed in a jig with ABS plastic spacers inserted to center the tank within the aluminum. The assembly is then foamed with an injector. Removable plastic hemispherical end caps for the covered tank are also insulated at this time. These caps are removable to allow plumbing connections in the field to the threaded fittings on the tank end caps.

Field Assembly Kit: Required fittings, pipes, brackets, etc., and field assembly instructions are packaged with each Interroof system. These fittings include special Swagelok fittings designed specifically for stainless steel piping and fittings and aluminum flashings and gaskets. A cradle for hanging the tank to the roof/collector made of 316 stainless is included in the kit. It is fabricated by forming and welding 3-in.-wide strips sheared from 16 gage sheet. The kit would also include a vacuum-formed ABS plastic drip pan designed to prevent roof or plumbing leaks from damaging ceiling material. This pan, too large to be produced on ELI's vacuum former, would be a purchased item. Assembly kits, collectors, and tanks are palletized in groups for shipping to Arizona by dedicated truck. We assume that 50 assemblies could be packed into one trailerload.

Direct Manufacturing Costs

We estimated direct time and material costs. (The figures are not included here because they are proprietary.) Labor costs are partially loaded to include employee benefits such as vacation, sick leave, retirement, Social Security, etc. Our estimate indicates that about 20 labor hours are needed to build each unit. To build 1000 units per year, the plant needs to produce four units per day. This corresponds to 80 man hours per shift, or 10 FTEs. At the higher production rate, we believe that the labor costs could be somewhat lower, owing to economies of scale. We believe that 20 FTEs could successfully produce 3000 units per year. We have not included this potential economy in our estimate of the labor costs for the higher production rates.

The material costs can be expected to remain the same at both production rates, since these costs depend on commodity prices and not purchased quantities.

Machinery Utilization

Examining the manufacturing time for the various assembly procedures, it is apparent that the most heavily utilized machine is the laser welder. The follows from the 100-minute estimate for the setup and welding time for the 10 tube/fin assemblies that are welded for each absorber assembly. At the production rate of 3000 units per year (approximately 12 units per day), the 100-minute-per-absorber estimate indicates that the laser welder would need to be operated 20 hours per day. Clearly at the higher production rates, ELI would need to improve welder throughput or a second welder would need to be added to the line.

Estimated Sales Price, FOB Arizona

Table 4 includes a number of additions to the direct manufacturing costs that must be covered by the selling price. (The table shows the elements that were cost-estimated, but the numbers are not included here because they are proprietary.) These additions include the costs of factory overhead (\$K/month), shipping from Florida to Arizona, warehousing, profit, and recovery of startup expenses. Please note that what is a reasonable profit for this hardware is very much in the eye of the beholder. The entrepreneurs who risked capital to set up this production line will see a need for significant profit to cover the substantial uncertainty about the strength of the solar hot water heater market. The salesman who sees sales strongly connected to price will look for lower profit figures.

We have only estimated installation costs. We have assumed that the most favorable conditions would need at least two workers to take two hours to install the collector and tank in a prepared rough-in. This would be followed by a plumber working for one hour to complete the final plumbing connections. Total installation cost for this scenario, assuming \$25/hour for construction labor and \$50/hour for plumbing, is \$200. Other installation cost factors are the traditional contractor markup on both the delivered cost of the system and on contractor labor costs. We have included 15% markups for both these items.

Table 4. Installed costs for the Interroof system.

Production quantity, per year:	1000	3000
Labor and materials, incl. 10% scrap and 10% rework		
Recovery of startup costs (2 year), incl. 10% interest	\$	\$
Per unit plant overhead, See Table 4	\$	\$
Shipping costs, 50 units/load, \$/trailer	\$	\$
Warehousing costs, Arizona, \$/mo	\$	\$
Profit, 15% of direct and indirect costs, excl. installation	\$	\$
Sales cost to contractor, FOB Arizona warehouse:		
Installation cost, incl. 15% contractor markup	\$	\$
Contractor appliance markup, 15%	\$	\$
Installed system cost to homeowner:		\$

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