June 2000 • NREL/BK-610-28044

Solar Buildings Program Contract Summary

Calendar Year 1999

National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401-3393

NREL is a U.S. Department of Energy Laboratory
Operated by Midwest Research Institute • Battelle • Bechtel

Contract No. DE-AC36-99-GO10337

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Prepared under Task No. SH01.6001

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Introduction

The mission of the U.S. Department of Energy's Solar Buildings Program is to advance the development and widespread deployment of competitive solar thermal technologies for use in buildings. The long-term goal of the Program is to combine solar energy technologies with energy-efficient construction techniques and create cost-effective buildings that have a zero net need for fossil fuel energy on an annual basis.

The Solar Buildings Program conducts research and development on solar technologies that can deliver heat, light, and hot water to residential and commercial buildings. By working closely with manufacturers in both the buildings and solar energy industries and by supporting research at universities and national laboratories, the Solar Buildings Program brings together the diverse players developing reliable and affordable solar technologies for building applications.

The National Renewable Energy Laboratory (NREL) in Golden, Colorado, and Sandia National Laboratories (SNL) in Albuquerque, New Mexico, jointly participate in the Solar Buildings Program. These two national laboratories work closely with industry researching new concepts, developing technology improvements, reducing manufacturing costs, monitoring system performance, promoting quality assurance, and identifying potential new markets.

In calendar year 1999, the Solar Buildings Program focused primarily on solar hot water system research and development (R&D), U.S. industry manufacturing assistance, and U.S. market assistance. The Program also completed a number of other projects that were begun in earlier years. This Contract Summary describes the Program's contracted activities that were active during 1999.

Research and Development

Two years ago, the Solar Buildings Program set a goal of **cutting the cost of solar water heaters in half** (from their current price range of $2000-$4000) **by 2003**. Achieving this goal would not only increase the market share of solar water heaters (potentially reducing energy cost and consumption) in this country, but would strongly position the U.S. solar industry in rapidly growing solar markets overseas. In an effort to meet this goal, both the National Renewable Energy Laboratory and Sandia National Laboratories have been actively investigating the use of low-cost polymer materials in the design of the "next-generation" of solar water heating systems.

In fiscal year 1998 (FY98), a Request for Proposals (RFP) entitled "New Concepts for Solar Thermal Systems" was issued and ten Phase 1 awards were made to small businesses and universities. After a Phase 2 "New Concepts" RFP in FY99 and an RFP focused on "Innovative, Low-Cost Solar Water Heating Systems," groups of competitive awards were made to several solar industry manufacturers and university research teams to focus on low-cost solar water heating systems. These cost-shared contracts included work with the following companies that will soon be developing and testing field-scale prototypes of low-cost system designs:

- FAFCO, Inc. (Redwood City, California)
- Solar Development, Inc. (Riviera Beach, Florida)
- Sun Systems, Inc. (Scottsdale, Arizona)
- Davis Energy Group (Davis, California)
- SunEarth, Inc. (Honolulu, Hawaii)
- University of Central Florida (Orlando, Florida).

Descriptions of these contracts have been omitted from this document because of proprietary information concerns.

In addition, NREL established contracts with the following universities to support and refine the low-cost system designs and the polymer manufacturing processes:

- University of Akron (Akron, Ohio)
- Colorado School of Mines (Golden, Colorado)
- University of Minnesota (Minneapolis, Minnesota)
- University of Wisconsin (Madison, Wisconsin)
- University of Colorado (Boulder, Colorado)

A performance and cost analysis support infrastructure for the Program's partners was also put in place in 1999. Contracts were issued to four consultants in thermal analysis and two project consultants.

Solar Hot Water Heating Systems—Identification of Plastic Materials

(NREL Subcontract No. TAR-9-29449-01)

Contract Summary
December 1999

Contractor: **William J. Brittain (of the University of Akron)**
Akron, Ohio

Contact: William J. Brittain (330/972-5147)

Objective: The overall objective is to provide polymer expertise to solar equipment manufacturers who are developing designs for low-cost solar water heaters in order to reduce both manufacturing and installation costs.

Description: To be useful for the development of low-cost solar water heaters, information on the performance properties of commercially available plastics, resins, sheets, and films needs to be identified and assessed for each system design. Since the final cost of the solar water heating system is also a function of the manufacturing costs, there is also a need for information on low-cost manufacturing and assembly processes. Specific activities of the work include: 1) identification of commercially available plastics and plastic products, e.g., additives, blends, coatings, co-extrusions and laminates, that can be used for the individual components of solar water heating systems; 2) identification of low-cost manufacturing and assembly techniques, e.g., heat sealing, co-extrusions or snap fittings that can be used to process these plastics or plastic components into solar water heating systems; and 3) review of specific solar water heating system designs and response to manufacturers' questions with regard to the most promising plastics and plastic products, as well as low-cost manufacturing and assembly processes.

Progress: A Solar Water Heating Polymer Workshop was held July 16-17 at the University of Akron and was attended by the contractor's polymer experts, representatives from the solar companies, Sandia, and NREL. The workshop began with overview presentations on: solar water heating (by NREL), system concepts (by the solar company representatives), polymer materials, polymer additives, and polymer manufacturing (by the University of Akron polymer experts), polymer heat exchangers (by the University of Minnesota), and polymer glazing testing (by NREL). The remainder of the workshop was devoted to a series of concurrent breakout sessions that allowed each solar company to interact directly with each of three polymer expert subteams (comprised of two experts each). The "break-out" sessions allowed detailed discussions about the innovative solar water heating designs and the ability to identify commercial candidate plastic products that may be used for the production of different components in these designs. These discussions allowed the manufacturers to ask questions about their designs and the contractor's team to educate the manufacturers and NREL on the strengths and weaknesses of various commercial plastic products and their manufacturing processes. The contractor is continuing to respond to follow-up questions from the manufacturers via telephone and e-mail.

Benefits: Solar manufacturers have been provided with assistance in the form of general information in workshop presentations, design reviews, system-specific discussions in

break-out sessions, and responses to follow-on questions. Technology gaps have been identified for the solar water heating system designs. These gaps include a lack of key performance information for promising plastics, e.g., the creep resistance at high temperature and under UV exposure as well as uncertainties on the commercial sources of specific grades or type of plastics. The technology gaps highlight areas where specific research may be needed to confirm the performance properties of the most promising plastics.

Period: June 1999–April 2000

		Funded	Cost-Share	Total
Amount:	FY99	$ 75,000		$ 75,000

Monitor: Craig Christensen (303/384-7510)

Solar Water Heating Systems—Identification of Plastic Materials

(NREL Subcontract No. TAR-9-29449-02)

Contract Summary
December 1999

Contractor: **PolyNEW, Inc.**
Golden, Colorado

Contact: John Dorgan (303/277-9033)

Objective: The overall objective is to provide polymer expertise to solar equipment manufacturers who are developing designs for low-cost solar water heaters in order to reduce both manufacturing and installation costs.

Description: To be useful for the development of low-cost solar water heaters, information on the performance properties of commercially available plastics, resins, sheets, and films needs to be identified and assessed for each system design. Since the final cost of the solar water heating system is also a function of the manufacturing costs, there is also a need for information on low-cost manufacturing and assembly processes. Specific activities of the work include: 1) identification of commercially available plastics and plastic products, e.g., additives, blends, coatings, co-extrusions and laminates, that can be used for the individual components of solar water heating systems; 2) identification of low-cost manufacturing and assembly techniques, e.g., heat sealing, co-extrusions or snap fittings that can be used to process these plastics or plastic components into solar water heating systems; and 3) review of specific solar water heating system designs and response to manufacturers' questions with regard to the most promising plastics and plastic products, as well as low-cost manufacturing and assembly processes.

Progress: PolyNEW identified and assessed a range of candidate polymer glazing materials for low-cost solar water heating systems. PolyNEW team members also attended the Low-Cost Solar Water Heating Project Review meeting, November 8-9, 1999 at NREL, conducted a tour of the polymer laboratories at the Colorado School of Mines, and met with several of the solar manufacturers to provide design reviews. PolyNEW is continuing to respond to follow-up questions from the manufacturers via telephone and e-mail.

Benefits: Solar manufacturers have been provided with assistance in the form of design reviews and responses to follow-on questions. The report on polymer glazing materials for low-cost solar water heating systems provides an assessment of a range of candidate materials, and the accompanying database provides detailed information on material properties.

Period:	July 1999–April 2000			
		Funded	Cost-Share	Total
Amount:	FY99	$ 35,000		$ 35,000
Monitor:	Craig Christensen (303/384-7510)			

Polymer Heat Exchangers for Low-Cost Solar Water Heating Systems

(NREL Subcontract No. AXG-9-29419-01)

Contract Summary
December 1999

Contractor: **University of Minnesota**
Minneapolis, Minnesota

Contact: Dr. Jane Davidson (612/626-9850)

Objectives: The objectives of this project are to:

1. *Modeling:* develop general heat transfer models for heat exchanger configurations of interest in the development of low-cost SDHW systems;
2. *Testing:* develop test facility and test protocols for calibrating the general models to specific instances as well as for fundamental investigations;
3. *Materials*: define potential low-cost heat exchanger (HX) materials, including the acquisition of creep data at higher temperatures;
4. *Design*: develop cost-effective heat exchanger designs (manifold design, geometry, and manufacturing).

Description: The Solar Buildings Program is supporting development of low-cost SDHW systems. The majority of the designs under investigation are passive systems with unpressurized storage utilizing immersed heat exchangers to extract the stored energy. Design and performance of immersed heat exchangers in tilted enclosures with large aspect ratios has not been studied in the past. The largest uncertainties involve the coupled issues of knowing the storage side heat transfer coefficient and predicting stratification in the storage that is induced during a draw. Storage side heat transfer coefficients will be modeled as the Nusselt number Nu(Gr; GF), with the geometric factor GF incorporating length scales that are not incorporated in the Grashoff number Gr. Stratification will be studied experimentally and with computational fluid dynamics (CFD) to determine the appropriate form of a simple model suitable for annual simulation. When heat exchangers of interest become available, they will be tested for determination of specific model parameters. Although a serpentine copper HX will remain a viable alternative, effort is devoted to lowering cost and weight through use of small-diameter polymer tube bundles that can potentially be lower in cost and weight. Requirements for heat exchanger materials will be developed and used to screen available polymers. For polymers of interest, data for creep at high temperature and pressure appropriate for household plumbing will be taken. Finally, heat exchanger manifold design and manufacturing presents the largest uncertainty in HX construction. In collaboration with the Program's industry partners, manifold designs will be investigated and optimized.

Progress: Heat transfer models for immersed heat exchangers have been developed using the best available natural convection heat transfer correlations. The models are available for steady state analyses and have been imbedded in annual simulation tools such as TRNSYS. These tools are being used to determine heat exchanger sizing as a function of appropriate system parameters (e.g., collector area/draw volume has a large effect on the sensitivity of annual performance to heat exchanger parameters). A test facility incorporating a large aspect-ratio storage tank has been constructed. Heat exchangers can

be tested comparatively in a standard rectangular tilted tank, or be tested coupled with the actual intended storage tank. Materials suitable for heat exchangers have been defined, using a combination of NSF certification and engineering indices. Cross-linked polyethylene (PEX), polyamides, and filled polypropylenes have been identified as potentially suitable low-cost materials. Two manifold designs proposed by industry partners have been investigated. However, neither of the analyzed designs appeared capable of meeting the long-term creep requirements.

Results: A report on material requirements and identification of suitable materials has been published. A paper report detailing a procedure for the sizing of tube walls was distributed to industry. A heat transfer model has been made available in EES, and the same correlations have been imbedded in a new TRNSYS ICS model (Type 222).

Period: April 1998–September 2001

		Funded	Cost-Share	Total
Amount:	FY98	$ 64,934	$ 13,000	$ 77,934
	FY99	$100,000	$ 33,000	$133,000
	Total Project	$164,934	$ 46,000	$210,934

Monitor: Dr. Jay Burch (303/384-7508)

Development and Maintenance of Solar Thermal Energy Simulation Tools

(DOE Cooperative Agreement No. DE-FC36-96GO10152 and

NREL Subcontract No. AAR-9-29441-01)

Contract Summary
December 1999

Contractor: **Board of Regents of the University of Wisconsin System**
Madison, Wisconsin

Contact: Dr. Bill Beckman (608/263-1590)

Objectives: The objectives of the NREL contract are to:

1. Maintain and improve the Transient System Simulation (TRNSYS) program as well as provide for the use of the Engineering Equation Solver (EES) tool as a module in TRNSYS;
2. Improve the TRNSYS library of user-developed modules;
3. Identify and develop the simulation models most needed by the Solar Buildings Program and the solar industry;
4. Assist the Solar Rating and Certification Corporation (SRCC) in transitioning its TRNSYS simulation library to TRNSYS Version 15.

Description: Because of its unique characteristics, TRNSYS has been the simulation tool of choice for the solar thermal industry worldwide for many years. It is the only available tool for energy system simulations which is modular ("modules" corresponding to components are "hooked up" in arbitrary configurations) and extensible (new modules can be created for new devices). Significant leverage has also been developed with European contributors (e.g., a graphical user interface, building modeling, and HVAC modules). However, the development of new TRNSYS modules can be made considerably easier if it becomes possible to use steady-state heat transfer models developed with EES, the general equation-solution software with built-in thermodynamic functions. Another desirable TRNSYS feature is the inclusion of location-specific TMY weather files as a parametric variation. TRNSYS's characteristics also enable the establishment of a library of "user-supplied" modules, which has existed for many years. However, there have been no standards for documentation or validation of the modules. Standards for documentation and validation will be developed and applied to the modules that are identified as having the highest interest. Finally, SRCC adopted a simulation-based procedure for performing SDHW system ratings in 1990. Generic system input decks were developed using TRNSYS 13 and are still being used. However, TRNSYS 13 is no longer supported and numerous improvements to key modules have been made that require the use of the latest TRNSYS version. Assistance is needed to help SRCC convert its current library of simulation decks to be compatible with TRNSYS 15 and its new modules.

Progress: In TRNSYS 15 development versions, use of EES as a module by three different programming approaches has been demonstrated. However, TRNSYS/EES simulation

time increases dramatically, which will be a problem when large numbers of runs are done (e.g., parametric variations or optimization). Techniques for reducing the execution time are under investigation. Numerous bugs have also been identified and fixed and new documentation is under preparation. There has been no progress on cleaning up the TRNSYS library of user-supplied modules. New modules of interest have been developed and will be placed in the library (far exceeding requirements due to leveraged funding). Theses with new module development include: a) development of a detailed collector design program; b) development of regression tools for fitting models of heat exchangers and compressors to commonly-available manufacturer's data; c) development of a pool heat load model.

Results: TRNSYS 15 will be released in early 2000, allowing widespread use of EES files as TRNSYS modules. Theses on collector modeling, regression techniques, and pool modeling have been made available (12/99). The detailed collector model has proven very useful in understanding and incorporating the temperature dependence of top losses in recent analyses for performance and overheat protection of low-cost ICS systems.

Period: April 1996–April 2001

		Funded	Cost-Share	Total
Amount:	FY97 (DOE Agreement)	$275,000	$ 70,000	$345,000
	FY98 (DOE Agreement)	$151,890	$ 70,000	$221,890
	FY99 (NREL Subcontract)	$ 62,495	$ 70,000	$132,495
	Total Project	$489,385	$210,000	$699,385

Monitor:

Dr. Jay Burch (303/384-7508)

Overheat Protection for Solar Water Heating Systems

(NREL Task Order No. KAK-6-16810-17)

Contract Summary
December 1999

Contractor: **University of Colorado**
Boulder, Colorado

Contact: Dr. Mike Brandemuhl (303/492-8594)

Objectives: The objectives of this project are to:

1. *Preliminary design*: from literature review and interaction with NREL staff, develop temperature/time requirements and natural convection designs for overheat protection;
2. *Modeling*: develop analytical (correlation-based) models and numerical models (CFD) for most promising designs;
3. *Validation*: validate models with convection loop experiments;
4. *Optimization*: optimize designs for lowest cost to meet temperature objectives, in conjunction with selected industry partners;
5. *Recommendations*: generate and publish overheating design recommendations.

Description: The Solar Buildings Program is investigating polymers as an enabling technology for low-cost solar water heating systems. However, low-cost polymers also have low maximum operating temperatures. Polyethylene and polypropylene, for example, are limited to maximum temperature of ~ 80^{o}C when under stress, in order to keep long-term creep acceptably low. Overheat protection is needed if such low-cost materials are to be useful, even in integral collector-storage (ICS) systems. Overheat protection schemes include: 1) increase in system losses; 2) reduction in optical gain; 3) dumping of hot water; or 4) boiling. Due to its potential for low cost and reliability, one attractive option is increasing the loss coefficient internally through natural convection loops that dump heat through the system side and back walls. Both air and water loops will be considered. Key questions include how much heat dump capacity is needed to achieve specific temperature/time objectives, and whether such capacity can be achieved with internal convection loops.

Progress: Steady state models of overheat protection using natural convection loops have been developed and used to determine the loop conductance (UA_overheat) as a function of the temperature difference between ICS system storage and ambient. Three preliminary natural convection designs have been targeted: internal loops with air and water, and an external air loop (venting of the collector gap). Steady state models using the Engineering Equation Solver (EES) software have been developed for each case, using literature correlations for forced and natural convection heat transfer coefficients. Uncertainty is dominated by the choice of heat transfer and friction correlations, with ~50% uncertainty in overall overheat conductance predictions. Numerical modeling using the computational fluid dynamics (CFD) program FLUENT is underway to help reduce this uncertainty. In conjunction with a thermal consultant, a Transient System Simulation (TRNSYS) ICS model (Type 222) has been developed which incorporates a heat dump that is controlled as a function of storage temperature. Assuming pressurization (boiling is neglected), the model indicates that without overheat protection peak temperatures are

100-140°C (depending on ICS system optical gain and loss parameters). UA_overheat needed to limit the system peak temperature to 80°C is being determined. The air loops are predicted to limit temperature below 100°C, and the water loop below 90°C. Optimization of the loops is proceeding. Although uncertainty is still unacceptably large, the preliminary study indicates that the natural convection loops do have promise of keeping temperatures below boiling, but must be optimized before temperature can be kept below 80°C.

Period: April 1999 – December 2001

		Funded	Cost-Share	Total
Amount:	FY99	$ 50,000		$ 50,000

Monitor: Dr. Jay Burch (303/384-7508)

Thermal Analysis of Low-Cost Solar Water Heating Systems

(NREL Subcontract No. TAR-9-29420-02)

Contract Summary
December 1999

Contractor: **Mountain Energy Partnership (MEP)**
Nederland, Colorado

Contact: Greg Barker (303/258-7920)

Objective: The objective of this contract is the provision of thermal analysis support to NREL and the Program's partners involved in efforts to develop low-cost solar water heating (SWH) systems. MEP is to provide thermal analysis support in the following areas:

1. Specific low-cost SWH system concepts proposed by the solar industry companies,
2. Specific low-cost system concepts proposed by NREL and Sandia,
3. General characterization of the thermal performance of active and passive SWH systems.

Description: The analysis involves component-level heat transfer calculations and/or system-level simulations. Tasks include model development, sizing and optimization, performance analysis, assessment, and reporting. The specific analysis projects on which MEP works are specified by NREL on a case-by-case basis. NREL interacts with the contractor on an ongoing basis during the analysis with respect to the approach and details of each project.

Progress: TRNSYS simulations of ICS systems have been made for a wide range of conditions and provide insights regarding the role of storage volume in ICS systems, particularly with regard to draw patterns. Other parameters studied for a typical ICS system included stratification, collector properties, and geographic location. The MEP work completed to date was presented at the November 8-9, 1999 Innovative, Low-cost Solar Water Heaters project review under the title "Modeled Performance of ICS Systems". The major impact appears to be that some of the project contractors may re-evaluate their ICS system designs to see if a reduction in the amount of water storage is possible.

Period: February 1999–February 2001

		Funded	Cost-Share	Total
Amount:	FY99	$ 85,000		$ 85,000

Monitor:

Craig Christensen (303/384-7510)

Thermal Analysis of Low-Cost Solar Water Heating Systems

(NREL Subcontract No. TAR-9-29420-04)

Contract Summary
December 1999

Contractor: **North Carolina State University (NCSU)**
Raleigh, North Carolina

Contact: Richard Johnson (919/515-5269)

Objective: The objective of this contract is the provision of thermal analysis support to NREL and the Program's partners involved in efforts to develop low-cost solar water heating (SWH) systems. NCSU is to provide thermal analysis support in the following areas:

1. Specific low-cost SWH system concepts proposed by the solar industry companies,
2. Specific low-cost system concepts proposed by NREL and Sandia,
3. General characterization of the thermal performance of active and passive SWH systems.

Description: The analysis involves component-level heat transfer calculations and/or system-level simulations. Tasks include model development, sizing and optimization, performance analysis, assessment, and reporting. The specific analysis projects on which NCSU works are specified by NREL on a case-by-case basis. NREL interacts with the contractor on an ongoing basis during the analysis with respect to the approach and details of each project.

Progress: The NCSU contract was finally placed recently after significant delays due to legal concerns at the university. There hasn't been any work under this "time and materials" contract and it is expected there probably won't be during FY 2000, given the program's budget level and the focus on the other thermal support contractors.

Period: June 1999 – June 2001

		Funded	Cost-Share	Total
Amount:	FY99	$ 40,000		$ 40,000

Monitor:

Cr

aig Christensen (303/384-7510)

Thermal Analysis of Low-Cost Solar Water Heating Systems

(NREL Subcontract No. TAR-9-29420-01)

Contract Summary
December 1999

Contractor: **Thermal Energy System Specialists (TESS)**
Madison, Wisconsin

Contact: Timothy McDowell (608/274-2577)

Objective: The objective of this contract is the provision of thermal analysis support to NREL and the Program's partners involved in efforts to develop low-cost solar water heating (SWH) systems. TESS is to provide thermal analysis support in the following areas:

1. Specific low-cost SWH system concepts proposed by the solar industry companies,
2. Specific low-cost system concepts proposed by NREL and Sandia,
3. General characterization of the thermal performance of active and passive SWH systems.

Description: The analysis involves component-level heat transfer calculations and/or system-level simulations. Tasks include model development, sizing and optimization, performance analysis, assessment, and reporting. The specific analysis projects on which TESS works are specified by NREL on a case-by-case basis. NREL interacts with the contractor on an ongoing basis during the analysis with respect to the approach and details of each project.

Progress: A simplified model of an ICS system in EES has been delivered to NREL for analysis and comments. This model has been incorporated into a TRNSYS input file and encapsulated in the TRNSED software, so that parametric studies and further evaluations are easier to accomplish. A short report detailing the model assumptions and the results from a component heat transfer test were delivered to NREL. A new version of this program was sent to the University of Minnesota (UM) for their continued usage. A TRNSYS input file utilizing the new ICS model was also written for UM for their analysis of ICS behavior. Several questions concerning the function of the model with a mixing valve were answered and new versions of the source code and documentation were delivered to UM.

Period: February 1999 – February 2001

		Funded	Cost-Share	Total
Amount:	FY99	$ 85,000		$ 85,000

Monitor: Craig Christensen (303/384-7510)

Thermal Analysis of Low-Cost Solar Water Heating Systems

(NREL Subcontract No. TAR-9-29420-03)

Contract Summary
December 1999

Contractor: **Wortman Engineering**
Longmont, Colorado

Contact: David Wortman (303/652-2118)

Objective: The objective of this contract is the provision of thermal analysis support to NREL and the Program's partners involved in efforts to develop low-cost solar water heating (SWH) systems. Wortman is to provide thermal analysis support in the following areas:

1. Specific low-cost SWH system concepts proposed by the solar industry companies,
2. Specific low-cost system concepts proposed by NREL and Sandia,
3. General characterization of the thermal performance of active and passive SWH systems.

Description: The analysis involves component-level heat transfer calculations and/or system-level simulations. Tasks include model development, sizing and optimization, performance analysis, assessment, and reporting. The specific analysis projects on which Wortman works are specified by NREL on a case-by-case basis. NREL interacts with the contractor on an ongoing basis during the analysis with respect to the approach and details of each project.

Progress: Some work has been done under the contract, but further work has been on hold because of illness of the principal investigator. A draft report has been prepared on solar hot water technologies in residential building codes. Recommendations are given for future action to make building codes more accommodating to solar hot water technologies. The report also recommends developing a synergy between solar hot water and photovoltaic systems when proposing code language changes, since the installation of solar hot water equipment and PV panels involve many overlapping issues. If such work can be coordinated, it appears reasonable that organizations supporting both technologies could work together to implement the appropriate revisions and additions to the codes.

Period: February 1999 – February 2001

		Funded	Cost-Share	Total
Amount:	FY99	$ 40,000		$ 40,000

Monitor: Craig Christensen (303/384-7510)

Cost Modeling of Solar Water Heating Systems

(NREL Subcontract No. TAR-7-1778-01)

Contract Summary
December 1999

Contractor: **Science Applications International Corporation (SAIC)**
Germantown, Maryland

Contact: Bob Lorand (703/356-4439)

Objectives: The objectives of this project are to:
1. Provide program assistance, as requested;
2. Develop a general framework for cost models of SDHW systems;
3. Develop baseline cost models for an active system and for an ICS system;
4. Assist low-cost water heating contractors in developing cost estimates for their solar domestic hot water (SDHW) concepts.

Description: In order to identify the most promising solar energy systems and to quantify related technical and market attributes, various cost assessments and financial systems analysis activities are needed. SAIC will assist NREL in proposal reviews, assessments of long-range plans, development of program metrics and impacts, cost analyses for solar cooling and water heating systems, developing general cost models, developing specific cost data and models for baseline systems, and assisting low-cost solar system contractors in developing cost estimates.

Progress: SAIC participated in the "New Concepts for Solar Thermal Systems" proposal review. A cost model was developed for solar cooling systems. A cost model was developed for solar water heating systems. A survey of selected solar manufacturers was done to determine baseline SDHW costs. The survey results were translated in two "baseline" systems, an ICS system and an active glycol system. Baseline data have been archived and presented in program meetings.

Period: October 1997–April 2000

		Funded	Cost-Share	Total
Amount:	FY97	$ 18,750		$ 18,750
	FY98	$ 31,250		$ 31,250
	FY99	$ 30,000		$ 30,000
	Total Project	$ 80,000		$ 80,000

Monitor: Dr. Jay Burch (303/384-7508)

Support for Innovative, Low-Cost Solar Water Heater Technology Development

(NREL Consulting Agreement No. CXL-9-2938-01)

Contract Summary
March 2000

Contractor: **Clifton Carwile (Consultant)**
Rockville, Maryland

Contact: Clifton Carwile (301/929-1953)

Objective: The objectives of this activity are to: 1) provide technical support to the Solar Heat and Buildings Technologies Program in working with subcontractors in developing concepts for innovative, low-cost solar water heaters; and 2) provide support to the Program in analyzing the results from the subcontractors' technology development activities.

Description: The activity involves the following: 1) serving as an interface between the solar companies developing innovative concepts and NREL's polymer and other materials specialist subcontractors—supporting them in requesting and getting access to these resources; 2) serving as an interface between NREL and the solar technology development subcontractors in getting access to NREL's costing and costing analysis consultants; 3) providing support to the technology development subcontractors in reporting on their activities; and 4) providing support to NREL in evaluating the subcontractors' work.

Progress: The consultant has been providing ongoing support to the solar water heater technology development subcontractors on behalf of the Program's task leader. In addition, the consultant has been providing support to the task leader with respect to ad hoc efforts relating to the technology development activities.

Period: March 1999 – December 31, 2000

		Funded	Cost-Share	Total
Amount:	FY99	$ 25,000	$	$ 25,000

Monitor: Russell Hewett (303/384-7463)

Advanced Applications

In FY97-98, the Solar Buildings Program began research into solar absorption cooling. However, due to limitations in FY98 funding, it was decided that the program could only afford to focus on solar hot water system research and development. Therefore, this section describes the solar cooling projects that were still underway in 1999.

This section also includes project descriptions of six of the Phase I "New Concepts for Solar Thermal Systems" contracts that were completed in 1999 as well as the scaling work conducted by the University of Texas at Austin.

Development of a Low-Cost Roof-Mountable Parabolic Trough for Absorption Cooling

(NREL Subcontract No. ADC-8-17672-03)

Contract Summary
December 1999

Contractor: **Industrial Solar Technology (IST)**
Golden, Colorado

Contact: E. Kenneth May (303/279-8108)

Objective: The objectives are to: 1) develop a low-cost, roof-mountable parabolic trough concentrating solar collector that can be used to power both single-stage and two-stage absorption cooling systems; and 2) test and evaluate prototypes.

Description: The project involves the production of the parabolic trough in a unique and functional way. IST has determined that by buckling a pre-curved sheet metal reflector, the buckled shape of the reflector very closely approximates a parabola. The sheet metal must first be mechanically deformed (with a standard sheet metal roller) to a given constant radius of curvature. The pre-curved reflector sheet will then be pressed together along its opposing edges until the reflector sheet buckles elastically. By buckling the reflector sheet the correct pre-determined amount (defined by a welded top frame), the sheet assumes a nearly parabolic contour. The net result is expected to be a highly accurate parabolic trough solar collector consisting of a few simple pieces made from off-the-shelf aluminum sheets and extrusions. In addition to development of the parabolic collector, the project involves: a) development of the collector drive and control components; b) development of the system and structure for roof-mounting; and c) development of a detailed plan for commercializing the technology for solar cooling applications.

Progress: IST has completed development of the design for the parabolic trough collector. One module has been fabricated, tested and evaluated. IST has also completed development of the designs for the collector drive/control subsystem and the roof-mounting subsystem. Development of the detailed commercialization plan is in progress.

Period: May 1998 – December 1999

		Funded	Cost-Share	Total
Amount:	FY97	$ 93,508	$ 23,377	$116,885

Monitor: Russell Hewett (303/384-7463)

Dual-Fired Generator for Gas/Solar Absorption Chillers
(NREL Subcontract No. ZAR-8-17672-02)

Contract Summary
December 1999

Contractor: **The Ohio State University (OSU) Research Foundation**
Columbus, Ohio

Contact: Dr. Richard Christensen, Principal Investigator (614/292-0445)
Dr. Jiming Cao, Acting Principal Investigator (614/292-0812)

Objective: The objective of the project is to design, optimize, test, and evaluate a generator for a 50-ton double-effect absorption chiller that is powered by solar thermal energy (and by natural gas when solar energy is insufficient or unavailable). Two heat exchanger concepts (proprietary to Ohio State University) will be investigated for use with the generator: 1) a concept using a plate fin type construction that uses three concentric shells; and 2) a concept involving use of a shell and tube heat exchanger.

Description: The project involves the following tasks: 1) installation of the 50-ton absorption chiller in the High Bay Laboratory of the OSU Mechanical Engineering Department; 2) testing the chiller using natural gas under steady state operation to insure that it is operating at optimum conditions; 3) design and fabrication of two dual-fired (hot water and gas) generators and heat exchangers for testing in the 50-ton chiller; 4) installation of the new generators and heat exchangers in the chiller; 5) testing and evaluation of the generator and heat exchangers using both gas and steam to simulate the temperature and heat input from a solar source; 6) formulation of the final designs for the generator and heat exchanger based on results from the testing; 7) performing a generator cost analysis; and 8) shipping the system to Duke Solar for additional evaluation.

Progress: OSU installed the 50-ton absorption chiller in the High Bay Laboratory and completed testing it under steady state operation using natural gas. The experimental data collected were compared to the ABSIM-OSU computer model. OSU completed fabrication of their generator concept and heat exchangers and installed the new concept into the chiller (replacing the original generator). OSU is currently in the process of testing and evaluating the new concepts using both natural gas and steam (to simulate solar thermal input) as the energy source.

Period: April 1998 – December 1999

		Funded	Cost-Share	Total
Amount:	FY98	$ 68,748	$ 17,292	$ 86,040

Monitor: Russell Hewett (303/384-7463)

Near-Commercialization Venture for Solar-Assisted Air Conditioning System in Puerto Rico

(NREL Subcontract No. ADC-8-17672-04)

Contract Summary
December 1999

Contractor: **University of Puerto Rico at Mayaguez (UPRM)**
Mayaguez, Puerto Rico

Contact: Dr. Jorge E. Gonzalez (787/832-4040 Ext. 2358)

Objective: The objective of the project is to generate a reliable, commercial, cost-competitive solar-assisted absorption cooling system for operation in Puerto Rico by 1999. The intended market for the cooling systems is light commercial establishments with cooling loads in the 10-25 ton range.

Description: The project involves the following efforts: 1) optimizing the overall operation and load dispatchability of the experimental absorption cooling system installed in Cabo Rojo, Puerto Rico (including designing and installing a thermal storage system and installation of a highly-efficient propane-fired boiler); 2) design, development, installation, and testing of a low-cost control system capable of controlling overall operation of the solar-assisted system; 3) operating, monitoring, and evaluating the thermal performance of the cooling system using non-conventional flat plate collectors with the potential to deliver hot water at temperatures higher than 100 degrees C (e.g., flow-through evacuated tubes and compound parabolic concentrators); 4) generation of complete installation and O&M manuals based on monitoring of the experimental system; and 5) initiation of an aggressive marketing strategy that will pave the way to full commercialization.

Progress: UPRM completed design and installation of a hot water thermal storage system for the absorption chiller that provides for three levels of temperature stratification. UPRM also completed design and installation of the control system to optimize operation and dispatchability. It uses two three-way valves that divert hot water flow between the solar collectors and the storage tank and from the tank to the absorption chiller. The system is fully instrumented for technical performance monitoring. UPRM is in the process of operating and evaluating the performance of the system using different types of solar collectors. They include flat plate collectors with Black Forest selective coatings (manufactured by Universal Solar) and heat pipe evacuated tube collectors (manufactured by Thermomax). Plans also call for testing and evaluating operation of the system using compound parabolic concentrators. However, based on results to date, economic viability of the technology for use in the Caribbean Basin has not been demonstrated. The project has resulted in development of a design tool for stratification manifolds for hot water storage tanks used in solar cooling systems.

Period:	May 1998 – December 1999			
		Funded	Cost-Share	Total
Amount:	FY98	$100,000	$144,478	$244,478
Monitor:	Russell Hewett (303/384-7463)			

Thin Film Absorber Flat Plate Solar Collector

(NREL Subcontract No. ADC-8-17675-03)

Contract Summary
December 1999

Contractor: **Access Technology Corporation**
Bangor, Maine

Contact: Mr. Tom Gocze (207/947-2750)

Objectives: The objectives of this project are to:
1. Develop designs for thin film collectors;
2. Search for suitable, low-cost polymeric materials;
3. Construct and test collector prototypes;
4. Perform system cost projections.

Description: Thin film collectors have been considered by Brookhaven, Honeywell, and Acurex. Generally these collectors were heat welded and were pressurized. However, it was difficult to keep the welds from separating. This project considers thin film collectors in a trickle-down mode of operation, which will reduce stress at the welds. The major problems to be addressed include: a) full wetting of the absorber, avoiding "hot spots"; b) manifold design, including internal seeming and use of inserted piping; c) identification of suitable low-cost materials. Prototypes will be constructed and tested. Collector costs will be projected. System designs will be considered and system costs analyzed.

Results: A design was developed which consisted of: a) a simple edge-welded bag absorber with clear top and black bottom; b) manifolds of copper tube with holes, fixed in the absorber with adhesives (GE RTV/TSE-392 worked well with nylon); c) a top cover of UV-protected, twin-wall polycarbonate (PMMA+UV absorber co-extrusion) bent into a "cover cap" with heated bars; and d) 2" polyisocyanurate insulation board, which is mechanically and adhesive bonded to the glazing cap. Two thin film prototypes were constructed of nylon and polysulphone thin films. Nylon and polysulphone were chosen as the best available low-cost film materials that can resist stagnation temperatures and can be easily welded with impulse welding. In both cases, the high surface energy of the film leads to good wetting of the films by the water without need for a capillary mat to distribute water evenly. Nylon films tended to "stick" together after operation with water, but not when a water/propylene glycol solution was used. Cost analysis indicated that the collector material plus labor costs are around $\$2/ft^2$, dominated by glazing cost. A drainback system was designed, using a proprietary "SofTank" design for storage. The SofTank is made from 3 layers of 3 mil PP film, held in ~ cylindrical tank shape via belted 2.5" polyisocyanurate insulation board which has been cut and shaped into a cylindrical form. Retail cost of a 90 gallon SofTank was estimated at $90. The SofTank design appears reliable and inexpensive for an unpressurized tank. System installed cost was estimated at about $1200, with $350 for a PV-driven gear motor pump. Further work is needed on system design to reduce the cost of the PV pump.

Period:	April 1998 – May 1999			
		Funded	Cost-Share	Total
Amount:	FY98	$ 48,000	$ 20,000	$ 68,000
Monitor:	Dr. Jay Burch (303/384-7508)			

New Concepts for Transpired Solar Collectors

Contract Summary
December 1999

Contractor: **Conserval Systems Inc.**
Buffalo, New York

Contact: John Hollick (716/835-4902)

Objective: This project investigated several areas with significant market potential for transpired solar collectors. The first area is converting overhead or garage doors typically found on homes and in industrial buildings to act as a transpired solar heater. The second area is to increase the temperature output of the transpired collector so that it can be used as a heater rather than a preheater in many process and space heating applications. The third area is documenting existing and new solar drying projects.

Description: For transpired collector solar doors, the contractor: 1) met with Overhead Door Corporation to select a standard door design; 2) designed a solar door prototype; 3) modified the base door as required; 4) designed a mating system for connecting the door to an air plenum; 5) selected a fan and control unit; 6) built and installed the prototype; 7) tested the operation and performance of the prototype; 8) modified the prototype as necessary and re-tested; and 9) reported on results.

For high-temperature transpired solar collectors, the contractor investigated two-stage unglazed/glazed transpired collectors and transpired collectors with selective absorbers. The contractor: 1) provided details of a proposed collector design; 2) reviewed modeling parameters; 3) discussed modeling results; and 3) reported on results.

Results: For transpired collector solar doors, prototype testing indicated that the solar door has performance similar to a standard transpired solar collector. For high-temperature transpired solar collectors, the selective absorber option was concluded to be the most attractive; therefore, Conserval will maintain contacts with Energy Laboratories Inc. to keep abreast of new licensees which may be able to supply coated material on wide sheets. In the meantime, Conserval will use two-stage unglazed/glazed transpired collectors for high temperature projects.

Period: June 1998 –December 1998

		Funded	Cost-Share	Total
Amount:	FY98	$ 37,350	$ 37,350	$ 74,700

Monitor: Craig Christensen (303/384-7510)

Solar Thermal Systems for Drying Coffee and Other High-Value Commodities

(NREL Subcontract No. ADC-8-17675-10)

Contract Summary
December 1999

Contractor: **Mesoamerican Development Institute**
Lowell, Massachusetts

Contact: Raul Raudeles (978/932-3460)

Objective: The objectives of this project were to: 1) refine and optimize the solar coffee-drying system design; 2) promote use of solar drying by working with international agencies such as the United Nations Development Program (UNDP); 3) develop new and improved systems; and 4) test systems in the field.

Description: Near-term activities focused mainly on improvements in system performance and operation in preparation for high-profile installations and demonstrations with the United Nations Development Program in Honduras. Longer-term activities focused on system optimizations, including alternative designs of system elements, and the testing of hybrid systems.

Results: A new easier-to-load coffee drying system was designed, prototyped, and built. Systems utilizing flat-plate solar collectors and a small transpired collector were designed and tested. A workshop on solar coffee drying systems, storage, and marketing strategies for solar-dried coffee was held in Costa Rica as a part of a conference for small growers from Latin America. An initial design and configuration for an Allspice leaf and berry drying system was developed. As appropriate, the results of these activities were applied in field tests at a research center at Montes de Oro.

Period: September 1998 – June 1999

		Funded	Cost-Share	Total
Amount:	FY98	$ 75,000	$ 34,540	$109,540

Monitor: Craig Christensen (303/384-7510)

Innovative Approaches to Solar Water Pasteurizers

(NREL Subcontract No. AAA-8-17675-07)

Contract Summary
December 1999

Contractor: **North Carolina State University / North Carolina Solar Center (NCSC)**
Raleigh, North Carolina

Contact: Rob Stevens (919/515-4092)

Objectives: The objectives of this project were to:

1. Develop designs for flow-through solar pasteurization systems using low-cost materials;
2. Develop TRNSYS models for the most promising designs;
3. Construct and instrument a pasteurizer test facility;
4. Build and test at least two pasteurizers to validate the TRNSYS models;
5. Provide "cost of water treatment" metrics for the most promising designs.

Description: Solar thermal-driven water pasteurization has not yet proved competitive with alternative water treatment techniques, due to high collector and heat exchanger (HX) costs that lead to a relatively high cost/(volume of water treated). On the village scale, a factor of 5 to 10 cost reduction is needed in order to be equal to solar PV-driven ultraviolet (UV) disinfection. On a smaller household scale, solar thermal pasteurization could have market impact, although it is unclear what cost target is needed (boiling is a very costly alternative). This project investigated promising designs and materials that could lower costs significantly. NCSC had previously begun work on a concept using the solar absorber surface as a preheater, which potentially could lower overall cost and increase output. Polymer materials were also examined for the collector and heat exchanger, since they have the potential of lowering costs significantly.

Results: TRNSYS models for solar pasteurizers both with internal and external heat exchangers were developed. Designs were sized to provide a minimum monthly average water volume of 160 liters/day. The model was used to determine optimal fixed tilt (e.g., near 53^{o} for Phoenix), although systems may be used with frequent tilt adjustments. The collector size for 160 lpd production was predicted to be 0.5-2 m^2, depending on the heat exchanger size. The TRNSYS model overpredicted performance about 40%, due to the lack of including collector/HX mass and thus ignoring warm-up periods (the model produced water instantly). The error was especially significant on partly cloudy days, but was not as severe on clear days. A test facility was constructed. Two solar pasteurization systems were built: a) traditional fin-tube copper/glass collector + an external shell-tube heat exchanger; and b) polymer collector (using coroplast, a polypropylene (PP) channeled material) with an internal heat exchanger. It turned out to be difficult to weld the PP material. Hot melt glue was finally used, contrary to indications from the manufacturer on other adhesives. Cost analysis confirmed that the polymer systems achieved the desired cost reduction, of at least a factor of five. However, durability of the polymer systems remains the most serious uncertainty. Two papers have been published, and a final report documenting all work is available.

Period:	April 1998 – May 1999			
		Funded	Cost-Share	Total
Amount:	FY98	$ 68,536	$ 20,000	$ 88,536
Monitor:	Dr. Jay Burch (303/384-7508)			

Development of Heat Pipe Technology for Solar Water Heating Systems

(NREL Subcontract No. AAA-8-17675-05)

Contract Summary
December 1999

Contractor: **Thermacore, Inc.**
Lancaster, Pennsylvania

Contact: Dr. Fred Phillips (717/569-6551)

Objectives: The objectives of this project are to: 1) develop and demonstrate capability of a "capillary pumped loop" heat pipe for passive heat transport between a rooftop collector and storage; and 2) develop concepts for overheat protection for solar domestic hot water (SDHW) systems using heat pipe technology.

Description: Heat pipe technology has always held some potential for providing a means for heat transport between a rooftop solar collector and a storage tank below. The pump and controller would be eliminated and smaller diameter connecting piping could be used. However, in a closed heat pipe there has to be a means to return the condensed fluid to the collector above. The distance is typically beyond the capability of wick pumping. Thermacore has developed for aerospace applications a technology called "capillary pumped loop", which uses the suction of capillary openings to pull fluid back to the collector. This technology has never been analyzed in the context of SDHW systems. Requirements will be defined, and the pumped loop designed and demonstrated for solar water heating systems. Concern over the toxicity of heat pipe fluids (e.g., methanol/water and ammonium) has led to consideration of other fluids such as acetone (although less attractive thermally). Heat pipe technology may also have a place in overheat protection, since the vapor pressure in the heat pipe is a function of temperature. A heat pipe with an appropriate pressure valve theoretically could control the system temperature.

Results: A general model of "capillary pumped loop" (CPL) heat pipes has been developed and validated. A 1 kW experimental loop was constructed to demonstrate an acetone CPL. Various system designs employing heat pipes were developed in conjunction with NREL staff. NREL staff was also briefed on heat pipe technology and issues in heat pipe usage were discussed in depth. Both evacuated tube and flat plate collectors were considered. The flat plate designs are more promising, with natural convection transferring heat from the collector to the CPL. It appears that ammonium may be acceptable as a working fluid, due to the small amount of the substance needed.

Period: April 1998 – September 1999

		Funded	Cost-Share	Total
Amount:	FY98	$ 68,152	$ 25,000	$ 93,152

Monitor: Dr. Jay Burch (303/384-7508)

Freezing of Potable Water Piping

(NREL Contract No. ZDC-8-17675-08)

Contract Summary
December 1999

Contractor: **Board of Regents of the University of Wisconsin System**
Madison, Wisconsin

Contact: Dr. Bill Beckman (608/263-1590)

Objectives: The objectives of this project are to:
1. Develop and validate models for the freezing of potable water piping;
2. Using extreme weather, determine as a function of pipe diameter and insulation the locations where it is safe to install solar water heating systems with insulated potable water pipes exposed to ambient conditions.

Description: Passive solar domestic hot water (SDHW) systems (integral collector-storage [ICS] and thermosiphon systems) are attractive because of the elimination of the pump/controller combination and the integration of the collector with storage. However, potable water supply/return piping is subjected to ambient conditions and can freeze (and possibly burst catastrophically) during extreme cold weather. Passive solar system manufacturers and installers have empirically settled upon the domain where they believe it is safe to install passive SDHW systems, but there has been no quantitative criteria defined. SRCC has developed a spreadsheet model for pipe freeze protection in its certification process, but the model is limited to the simple assumption of constant ambient conditions. Therefore, a physical model with varying ambient temperature will be developed and validated. In addition, a search will be made for possible solutions to the pipe freezing problem, which would allow the passive system domain to be extended.

Results: An EES model (constant ambient temperature) and a dynamic TRNSYS model (varying ambient temperature) have been made for predicting time to freeze. The models account for sensible cooling from a specified initial state to 0^{o}C and for removal of latent heat (neglecting any thermal resistance from forming ice) to a total frozen state. It is assumed there are no internal convection processes and that there is no draw. Time for pressure to build up from this point is not considered, since for copper pipe it was thought to be very small. Using data gathered in a recent University of Illinois project, the model was validated. It was shown that predictions were within the error band based upon uncertainty in the R-value of the insulation. Extreme weather data sets were then generated for 240 U.S. locations, using a procedure recently developed by the University of Wisconsin for ASHRAE. The dynamic TRNSYS model was run with these data sets, generating time to freeze under the extreme cold conditions. The results indicate that there are very few locations in the U.S. (~6) where freezing will *never* occur, for all the pipe geometries and insulation thicknesses investigated. This inconsistency with industry experience has not been resolved, although NREL suggested that probability of draws should be included to derive pipe freeze probability, rather than deriving absolute “safe” limits which are decidedly too conservative.

Period:	July 1998 – September 1999			
		Funded	Cost-Share	Total
Amount:	FY98	$ 54,010	$ 25,000	$ 79,010
Monitor:	Dr. Jay Burch (303/384-7508)			

Characterization of Scale in Solar Thermal Energy Systems

(DOE Grant No. DE-FG36-94GO10034 and

NREL Subcontract No. XXG-8-18414-01)

Contract Summary
December 1999

Contractor: **University of Texas at Austin**
Austin, Texas

Contact: Dr. Gary Vliet (512/471-3120)

Objectives: The objectives of the NREL contract are to:

1. Develop and maintain software for the prediction of scale in solar water heating systems
2. Develop a "scaling rate" experimental facility;
3. Improve models for scaling rate based upon experimental data;
4. Determine the scale propensity of polymer tubing relative to copper tubing.

Description: Calcium carbonate scale buildup in solar domestic hot water (SDHW) systems can lead to degraded performance and eventual failure. The University of Texas at Austin has been investigating the effect of scaling in SDHW systems under support from DOE and NREL since 1994. This has involved: reviewing the literature on scaling rate experiments and scaling rate models, developing scale rate models, developing software based on these models to predict the influence of scaling in SDHW systems, investigating SDHW design features which affect the rate of scale formation, collecting field data on scaling in SDHW systems, developing an improved model for prediction of scaling rates, and performing an experimental investigation to obtain better data for validating scaling models. There is also current interest within the SDHW community for the potential of using small-diameter polymer materials for heat exchange surfaces. If scale builds up in these tubes, the heat exchanger could degrade and fail prematurely. A search of the literature (journal papers and industrial literature) will be conducted to assess scale propensity in the polymeric materials that have potential for use in SDHW system heat exchangers. Limited screening tests will be conducted with up to three of those materials that appear to have the best potential based on the literature assessment.

Progress: The scale software model is available as the stand-alone windows program, SOLSCALE. An ASES paper and a contract report discussing the program have been published. A published review of experimental scaling data and scaling rate models from the literature indicates the scaling rate model used in the software may have limitations, particularly since the effect of bulk water temperature is not well-modeled. Since the published forms of water chemistry data vary, the current inputs of Ca, pH, Total Alkalinity and total dissolved solids are now being broadened. The calculation of solar system temperature distributions (dependent on system characteristics, site weather, and draw volume) using simulation-based correlations will also be improved. The scaling rate facility has been built and tested and the effect of bulk water temperature on scaling rate is being determined. In another paper, an assessment of several SDHW system designs was

conducted and it was recommended that an indirect system with a wraparound heat exchanger would be preferable in reducing the influence of scaling in scale prone waters.

Period: October 1994 - April 2000

		Funded	Cost-Share	Total
Amount:	FY95 (DOE Grant)	$ 25,000		$ 25,000
	FY96 (DOE Grant)	$ 30,353		$ 30,353
	FY97 (DOE Grant)	$ 35,316		$ 35,316
	FY98 (DOE Grant)	$ 35,315		$ 35,315
	FY98 (NREL Subcontract)	$ 25,000		$ 25,000
	FY99 (NREL Subcontract)	$ 10,000		$ 10,000
	Total Project	$160,984		$160,984

Monitor: Dr. Jay Burch (303/384-7508)

Simple Low-Cost Concentrating Collector with Evacuated All-Glass Absorber for Solar Cooling

(NREL Subcontract No. AAR-8-17672-01)

Contract Summary
September 1999

Contractor: **Solar Enterprises International (SEI)**
Chicago, Illinois

Contact: Dr. Roland Winston (773/241-5786)

Objective: The objectives of the project are to: 1) design and develop a state-of-the-art (potentially low-cost) concentrating solar collector consisting of a compound parabolic concentrator (CPC) and an all-glass evacuated tube absorber; 2) conduct preliminary tests to evaluate the projected performance of the collector; and 3) conduct supporting cost and performance modeling studies. The solar collector is to be designed for driving double-effect absorption cooling chillers having an operating temperature of 160 degrees C and a COP of 1.2. SEI is going into the project hoping to show that an installed cost of $20/sq ft is feasible.

Description: The project involves the following tasks: 1) identifying and procuring samples of commercially available high-quality glass tubes that can be configured into evacuated tube absorbers coated with Cermet and procuring commercially available U-tubes and fin heat exchangers; 2) designing and optimizing the CPC concentrator for the all-glass dewar-type absorber, taking advantage of advances in nonimaging design methodology; 3) designing and optimizing the absorber tubes (to be coated with new metallo-ceramic selective coatings)— to be compatible with the higher fluxes on the tubes due to concentration and higher operating temperature regimes; 4) selection of reflector materials and cover glazings; 5) development of the module design (i.e., packaging of the collector tubes into modules for ease of installation); 6) fabrication of at least one prototype module array for testing and evaluation; 7) laboratory testing and evaluation of the prototype array; and 8) development of a detailed cost model for estimating the cost of producing the solar collector.

Progress: SEI procured samples of commercially available components for possible use in their solar collector concept (i.e., all-glass dewar type absorber tubes with matching U-tube and fin heat exchangers) and sent them to Sandia for testing. This resulted in the identification of the materials that would be used. SEI then completed the optical and thermal design work for the collector concept and the design for the module package (including support for the reflector). They then fabricated an external compound parabolic collector (XCPC) module prototype and completed construction of a manual one-axis tracking test facility to be used to test it. SEI then completed a testing and evaluation program.

Results: This projected has resulted in development of an innovative concentrating, evacuated tube solar collector that has the potential to drive double-effect absorption chillers using the thermal energy from concentrated sunlight.

Period:	March 1998 – January 1999			
		Funded	Cost-Share	Total
Amount:	FY98	$ 99,304	$ 28,750	$128,054
Monitor:	Mary Jane Hale (303/384-7453)			

U.S. Market Assistance

During FY98, three solar water heating marketing research studies were completed. The studies were conducted by the NAHB Research Center (targeted at homebuilders, architects and trades contractors), FOCUS Marketing Services (targeted at recent new home buyers and solar homeowners), and Symmetrics Marketing Corporation (targeted at recent new home buyers). The Symmetrics study was conducted collaboratively with the Salt River Project Agricultural Improvement and Power District. During FY99, FOCUS Marketing Services, under an NREL subcontract, used the results from the three studies to formulate a national strategy and action plan for introducing solar water heating into the new homes construction industry.

During FY99, collaborative, cost-shared projects (established in FY98) also continued with three utilities that have solar business ventures or are actively investigating implementing such ventures. They are Lakeland Electric (Lakeland, Florida), the Eugene Water and Electric Board (Eugene, Oregon), and the Salt River Project Agricultural Improvement and Power District (Phoenix, Arizona). Also during FY99, the Program established a collaborative, cost-shared project with the Florida Energy Office (FEO) and the NREL Photovoltaics Program targeted at reducing codes, covenants, and restrictions (CC&Rs) as barriers to market acceptance and penetration of solar water heating and PV systems in residential communities. In addition, the Program contracted with ENSTAR Renewables Group to improve the Program's communications with the U.S. solar industry.

In FY98, through a competitive solicitation conducted for the Program by the DOE Golden Field Office, the Program established collaborative, cost-shared solar water heating market development projects with the Corporation for Solar Technology and Renewable Resources (CSTRR) in Las Vegas, Nevada, the Tucson Coalition for Solar (TCS), the Vermont Energy Investment Corporation (VEIC), and Wisconsin Public Service Corporation (WPSC). In FY99, an additional market project was established with American Dream Builders in Florida.

In FY98, the Program established a collaborative, cost-shared solar water heating market development project with Sun Systems and Cavco Industries to develop sustainable markets for solar technology in the manufactured homes industry. Cavco, one of the nation's largest producers of manufactured homes, is interested in investigating solar technology as a means for expanding its array of offerings, distinguishing itself from its competitors, and increasing its sales.

Opportunities for Solar Water Heating and Focus Group Workshops for New Home Builders Regarding Solar Water Heating

(NREL Subcontract No. AAD-7-17642-01)

Contract Summary
September 1999

Contractor: **NAHB Research Center**
Upper Marlboro, Maryland

Contact: Christopher J. Fennell (800/638-8556 Ext. 7221)

Objective: The objectives of this subcontract were to: 1) collect information regarding new home construction activity in states for which solar technology has promising potential; 2) conduct market research targeted at new home builders and others (e.g., architects) regarding the technical, economic, performance, and cost criteria that solar water heating must satisfy in order for them to consider offering it as a standard or optional feature in their developments; 3) develop a professional-quality audio-visual presentation that documents the results from the market research; and 4) conduct a marketing research study targeted at the conventional gas and electric water heating industry in order to get information regarding the features and performance that solar water heaters must have in order for this industry to get involved in offering it in some capacity.

Description: The first activity in the project involved using the NAHB Research Center (NAHBRC) new homes construction activity database and its projections algorithms to generate estimates of new construction activity in Arizona, California, Florida, Hawaii and Oregon for the period 1998 – 2001. These five states are states where solar systems are presently being marketed relatively successfully and/or where state tax credit programs exist. The Program then made the decision to focus the market research on Arizona, California and Florida. The marketing research involved: 1) selection of the sectors of the new homes markets on which to focus; 2) conducting qualitative (i.e., focus group sessions) solar water heating market research involving new home builders, architects and new home building trades contractors (e.g., plumbers and roofers) as well as recent new home buyers and prospective new home buyers; and 3) documenting the reactions and attitudes of the focus group participants regarding solar systems and then generating a report and a professional-quality audio-visual presentation that documented the findings, conclusions and recommendations. The subcontract also included conducting a sample survey of conventional gas and electric water heater producers and national dealers (e.g., Sears) to determine whether or not they would be interested in getting involved in solar water heating in some capacity and the conditions that must exist in order for them to do so.

Results: NAHBRC has successfully completed all efforts. For the five states of interest, NAHBRC generated estimates of construction activity (by market sector) out to 2001. In the market research, the focus was on homebuilders building “move -up” and “luxury” home in Arizona, California and Florida. Five focus sessions were conducted in these three states involving senior executives from over 50 regional and national homebuilders. NAHBRC also conducted one focus group session in Phoenix involving architects and one in Sacramento involving roofers and plumbers. All sessions were videotaped. NAHBRC then constructed an audio-visual presentation that documented the market research

findings. The presentation makes use of "snippets" extracted from the videotapes. NAHBRC also surveyed eight conventional gas and electric water heater manufacturing companies (by means of one-on-one structured interviews). They were queried regarding: 1) their experience (if any) with solar water heating; 2) attitudes and perceptions about solar water heating; 3) what solar water heaters ought to cost and how they should perform; and 4) what it would take for them to become involved in some capacity in the manufacturing and/or marketing of solar water heaters. In addition, NAHBRC gave them the opportunity to make recommendations to the solar industry and the Program for getting the technology more widely accepted in the market place. The results from the qualitative marketing research studies are documented in the report *"Opportunities for Solar Water Heating: Final Report"* (NAHB Research Center, January 1998). The results from the marketing research targeted at conventional gas and electric water heater manufacturers and national dealers are documented in the report *"Marketing Research Potential for Solar in the Conventional Gas and Electric Water Heating and HVAC Industry"* (NAHB Research Center, September 1998).

Benefits: The results from this subcontract (together with marketing research studies conducted for the Program by FOCUS Marketing Services and Symmetrics Marketing Corporation) have provided the Solar Buildings Program and the solar industry with the framework for designing and developing next-generation solar water heaters and making improvements to commercially available systems. In addition, the results from the studies have provided the Program, the solar industry, the Million Solar Roofs Initiative and other organizations (e.g., utilities, new home builders, etc.) with the underpinnings for formulating solar water heating market deployment and action plans.

Period: May 1997 – September 1998

		Funded	Cost-Share	Total
Amount:	FY97	$ 64,984		$ 64,984
	FY98	$ 29,984		$ 29,984
	Total Project	$ 94,968		$ 94,968

Monitor: Russell Hewett (303/384-7463)

Solar Water Heating Systems for the New Homes Market: Attitudes and Requirements of Actual and Prospective Users

(NREL Subcontract No. AAD-7-17646-01)

Contract Summary
September 1999

Contractor: **FOCUS Marketing Services**
Westlake Village, California

Contact: Laurie Lofland (805/449-4172)

Objective: The objectives of this subcontract were to: 1) conduct qualitative and quantitative market research to collect information from actual and prospective new home buyers (in selected sectors of the new homes market) regarding what features that solar water heaters must have in order for them to buy mortgage-financed, solar-equipped homes; 2) conduct focus group sessions targeted at homeowners that have owned solar water heaters for at least three years in order to collect information regarding their experiences with the technology; and 3) modify, upgrade, and generate a user's guide for an existing Excel-based computer model that determines the annual cash flows accruing from a solar water heater whose financing has been included in the mortgage.

Description: The project was specifically targeted at the new home market in Arizona, California and Florida. It involved the following tasks: 1) selection of the sectors of the new homes markets on which to focus; 2) conducting qualitative (i.e., focus group sessions) solar water heating market research involving recent new home buyers and prospective new home buyers; 3) conducting quantitative (i.e., a sample survey) solar water heating market research involving recent new home buyers; 4) conducting a focus group session involving homeowners that have owned and operated solar water heaters for at least three years in order to collect information regarding their experiences as well as get their recommendations regarding how to make the technology better; and 5) modifying an existing Excel-based solar water heater cash flow analysis model in order to make it more user-friendly and then, finally, generating a user's guide.

Results: FOCUS Marketing has successfully completed all efforts. The following three sectors of the new single-family homes market were investigated: "first time", "move-up", and luxury (as defined for each of the three target states). FOCUS then conducted five focus group sessions involving recent new homebuyers and prospective new homebuyers. In addition, 300 recent new homebuyers (without solar) were queried regarding their attitudes about solar systems and what they demanded in it. One focus group session was conducted in which solar system homeowners were queried regarding their experiences and their recommendations for making it better and how to promote it. FOCUS has also successfully completed upgrading the Excel-based cash flow analysis computer model. It has been configured into a tool that can be used by new home builders in order to show prospective buyers the monthly net savings they would accrue if they were to opt for a solar water heater and include its financing in the mortgage. FOCUS also completed development of a user's guide for the cash flow analysis model. The results from the qualitative marketing research studies and the study involving solar homeowners are documented in the report *"Deliverable 8: Final Report Documenting Results from*

Analysis of Task 2 Qualitative Research: Findings, Conclusions and Recommendations to NREL and the Solar Industry" (FOCUS Marketing Services, January 1998). The results from the quantitative marketing research studies are documented in the report *"Deliverable 8: Final Report Documenting Results from Analysis of Task 1 Quantitative Research: Findings, Conclusions and Recommendations to NREL and the Solar Industry"* (FOCUS Marketing Services, March 1998).

Benefits: The results from this subcontract (together with marketing research studies conducted for the Program by the NAHB Research Center and Symmetrics Marketing Corporation) have provided the Solar Buildings Program and the solar industry with the framework for designing and developing next-generation solar water heaters and making improvements to commercially available systems. In addition, the results from the studies have provided the Program, the solar industry, the Million Solar Roofs Initiative and other organizations (e.g., utilities, new home builders, etc.) with the underpinnings for formulating solar water heating market deployment and action plans.

Period: July 1997 – April 1998

		Funded	Cost-Share	Total
Amount:	FY97	$ 59,540		$ 59,540

Monitor: Russell Hewett (303/384-7463)

Salt River Project/NREL Collaborative Solar Water Heating Marketing Research Project

(NREL Subcontract No. AAR-8-18615-01)

Contract Summary
September 1999

Contractor: **Salt River Project Agricultural Improvement and Power District (SRP)**
Phoenix, Arizona

Contact: Ernest Pamolino—Salt River Project (602/236-3014)
Dr. Jonathan Masland—Symmetrics Marketing Corporation (510/283-1977)

Objective: The objective of this collaborative, cost-shared project with SRP was to conduct a quantitative marketing research study targeted at recent new home buyers regarding procuring solar water heaters for their homes. The research addressed: 1) what features that solar water heaters must have and how they must perform in order for new home buyers to select them when buying a new home; 2) solar trade-off studies (i.e., how prospective homebuyers would pick and choose from features that might be incorporated in a solar system, given a target selling price for the system); 3) solar-versus-other-options trade-off studies (i.e., how solar water heaters stack up against other options available to new home buyers; and 4) the psychographic characteristics of prospective buyers (i.e., studies regarding how decisions made about solar systems by homebuyers correlate with their values and attitudes about the environment).

Description: While the NREL subcontract was with SRP, the actual market research was performed by Symmetrics Marketing Corp. (Mesa, Arizona) -- a marketing research company that SRP has used in previous efforts involving the introduction of new products and services into the market place. The market research involved conducting one-on-one interviews with a sample of individuals and couples in two states that had purchased a new home within the past 24 months. The project involved: 1) selecting the states and the sectors of the new homes market to be included in the research; 2) specification by SRP and NREL of the issues and questions to be addressed as well as the desired outcomes of the research; 3) development of both the market research methodology and the props that were needed in working with the families participating in the study; 4) recruiting and selection of the samples of families; 5) conducting the research; 6) analysis of the data to generate information and draw conclusions; 7) formulation of recommendations to SRP and NREL and the solar industry regarding what the next steps should be with respect to developing the technology and marketing it; and 8) formulating recommendations regarding ways (if any) to improve the market research methodology and new lines of research to pursue.

Results: SRP and Symmetrics Marketing have successfully completed all efforts. Phoenix and Las Vegas were selected as the sites for the research. Two hundred families (100 with homes in the $100,000-$150,000 range and 100 with homes in the $150,000-$200,000 range) participated in Phoenix. One hundred homeowners having homes in the $100,000-$150,000 range participated in Las Vegas. Symmetrics completed the research methodology and conducted pretests in Phoenix to test and refine it. The methodology involved querying the participants about solar water heaters -- based on the knowledge

(or lack of knowledge) that they brought to the table when they were interviewed. Then, they were given a short familiarization briefing on today's solar water heaters and then re-queried regarding their attitudes. The participants were put through the solar design tradeoff exercise and a conjoint analysis to determine how they viewed solar water heaters compared to five other popular options available to homebuyers. Symmetrics conducted and completed the research involving the 300 participants in March 1998. The results from the marketing research studies are documented in the report *"SRP/NREL New Home Buyer Solar Water Heater Tradeoff Study: Summary Report for Public Release"* (Symmetrics Marketing Corporation, June 1998).).

Benefits: The results from this subcontract (together with market research conducted for the Program by FOCUS Marketing Services and the NAHB Research Center) have provided the Solar Buildings Program and the solar industry with the framework for designing and developing next-generation solar water heaters and making improvements to commercially-available systems. In addition, the results from the studies have provided the Program, the solar industry, the Million Solar Roofs Initiative and other organizations (e.g., utilities, new home builders, etc.) with the underpinnings for formulating solar water heating market deployment and action plans. In fact, SRP and Bomin Technologies Group are now using the results from this research to assess the feasibility of a business joint venture involving the manufacturing, selling and servicing of solar water heaters for selected sectors of the new homes market in the U.S. Southwest.

Period: December 1997 – July 1998

		Funded	Cost-Share	Total
Amount:	FY98	$ 60,000	$ 34,978	$ 94,978

Monitor: Russell Hewett (303/384-7463)

Solar Market Deployment Strategy: New Homes Market Development

(NREL Subcontract No. AAR-9-18498-01)

Contract Summary
September 1999

Contractor: **FOCUS Marketing Services**
Westlake Village, California

Contact: Cynthia Keller (805/449-4172)

Objective: The objective of this subcontract was to formulate a national strategy and work plan that the solar industry and other organizations could utilize to introduce solar water heaters into the new homes construction industry in a sustainable way. The strategy and work plan are to be formulated based on the lessons learned and the knowledge gained from three solar water heating market research studies conducted for the Solar Buildings Program. The studies were conducted by FOCUS Marketing Services, the NAHB Research Center, and Symmetrics Marketing Corporation.

Description: The project involved the following four tasks: 1) investigation of practices and procedures commonly used by manufacturers selling products in the new residential construction industry in order to determine whether or not they could be used to market solar water heaters; 2) analysis of the results and conclusions from the three NREL-sponsored solar water heating market research studies in order to identify the key messages that could be used in crafting a product deployment strategy; 3) formulation of a solar water heater market deployment strategy using these messages and the contractor's market development expertise; and 4) collection of a sample of tools and promotional materials that are used by manufacturers of appliance-type products, i.e., manufacturers that are successfully selling to new home builders.

Results: FOCUS Marketing has successfully completed all efforts. FOCUS identified a sample of manufacturers (or their major distributors) in Arizona, California and Florida that are successfully selling appliance-type products to new home builders. FOCUS then conducted telephone interviews with the manufacturers to obtain qualitative data regarding distribution channels, marketing strategies, and promotional materials as well as successful and unsuccessful marketing programs. The analysis of the three NREL-sponsored market research studies resulted in the identification of three essential themes and messages on which to focus in formulating the market deployment strategy. FOCUS then generated the solar water heating market deployment strategy (a draft version and then a revised version). Finally, FOCUS collected and submitted a large number of examples of promotional materials used by various manufacturers selling to new home builders -- materials that could serve as models for generating solar promotional materials.

Benefits: This subcontract has resulted in development of a strategy and work plan that an individual solar company, the solar industry as a whole, and other organizations (e.g., utilities) could follow to develop markets for solar water heaters on a sustainable basis. The strategy and work plan is documented in the report *"Task 3: Creation of A Comprehensive Product Deployment Strategy Based on Existing Successful Strategies"* (FOCUS Marketing Services, July 1999). The strategy and work plan assumes that the

entity seeking to develop markets for solar water heaters has a relatively long-range outlook (i.e., two to three years).

Period: December 1998 – July 1999

		Funded	Cost-Share	Total
Amount:	FY98	$ 45,000		$ 45,000

Monitor: Russell Hewett (303/384-7463)

Solar Swimming Pool Heating Marketing Research Study

(NREL Subcontract No. AAR-8-18482-01)

Contract Summary
September 1999

Contractor: **Synapse Infusion Group, Inc**.
Westlake Village, California

Contact: Gail Fridstein (818/707-3499)

Objective: One objective of the subcontract was to conduct a market research study targeted at homeowners with solar-heated swimming pools in order to collect information about their demographics and their experiences with and attitudes about their solar systems. The other objective was to conduct a market research study targeted at homeowners with unheated swimming pools in order to collect information regarding their demographics and what features that solar pool heaters must have in order for them to consider them as a pool heating option. The goal in both studies was to collect information for use in better promoting solar pool heating and increasing its market acceptance and penetration.

Description: The project involved conducting a quantitative (i.e., involving a sample survey) market research study targeted at homeowners with solar-heated swimming pools in Arizona, California and Florida. It also included conducting a quantitative market research study targeted at homeowners with unheated swimming pools in Arizona, California and Florida.

Results: Synapse Infusion successfully completed the marketing research studies and documented the results and conclusions in a final report. The marketing research study targeted at homeowners with solar-heated pools involved 230 families. The study targeted at homeowners with unheated pools (or pools heated using a means other than a solar system) included 224 homeowners. In addition to querying both samples regarding their attitudes about solar pool heating, Synapse Infusion tallied their demographic profiles.

Benefits: The marketing research conducted by Synapse Infusion through this contract provide the most up-to-date information on: 1) the demographics of homeowners having solar-heated pools and their attitudes about their solar systems; 2) what features that solar pool heaters must have and how they should perform in order to compete with other pool heating options; and 3) recommendations to the solar industry regarding actions it should take in order to increase solar market acceptance and penetration. The findings, conclusions, and recommendations are documented in the final report *"Report on Solar Pool Heating Quantitative Survey"* (Synapse Infusion Group, Inc., January 1999).

Period: September 1998 – January 1999

		Funded	Cost-Share	Total
Amount:	FY98	$ 24,900		$ 24,900

Monitor: Russell Hewett (303/384-7463)

Market Development/Business Development/Operating Plan For A Utility/ESCO Solar Water Heating Business Venture

(NREL Subcontract No. TBW-8-18628-01)

Contract Summary
September 1999

Contractor: **Comer and Associates** (d.b.a. Energy Alliance Group)
Boulder, Colorado

Contact: Jerry Comer (303/786-7986)

Objective: The objective of the contract was the development of a comprehensive business plan that the Lakeland, Florida municipal electric utility, Lakeland Electric, could utilize to guide the pilot phase of a solar water heating distributed generation project. The objective of the distributed generation project is the development of an energy services venture in which a utility installs solar water heaters on their customers' homes (systems that the utility owns and operates) and then meters and sells the energy delivered by the systems to the homeowners.

Description: The Lakeland Electric project is a solar water heating distributed generation program involving the Florida Energy Office (FEO) of the Florida Department of Community Affairs, the Florida Solar Energy Center (FSEC), Lakeland Electric, and NREL. (Lakeland Electric provides electric and water service in the central Florida area south of Disney World – a rapidly growing population area.) NREL's contract with Comer and Associates involved: (1) establishing the financial, economic, and market development baselines for the program; (2) specifying the target market and how solar systems are to be marketed; and (3) generating the final version of the business plan to guide the implementation of the pilot phase.

Results: Comer and Associates successfully completed all the tasks associated with the project. The business plan *"Cost-Effective Solar Water Heating Program: A Business Report for the Implementation of a Residential Pilot Program"* is currently being used by Lakeland Electric in the implementation of the pilot phase.

Benefits: The first 25 solar installations have been completed. Lakeland Electric is now in the process of seeking funding from FEO in order to expand the program in its service territory. The business plan has also been made available to other Florida utilities as a model for implementing similar ventures.

Period: March 1998 – December 1998

		Funded	Cost-Share	Total
Amount:	FY98	$ 38,433	$500,000	$538,433

Monitor: Russell Hewett (303/384-7463)

Collaborative Solar Water Heating Marketing Research and Market Development Project

(NREL Subcontract No. AAF-8-18627-01)

Contract Summary
December 1999

Contractor: **Eugene Water and Electric Board (EWEB)**
Eugene, Oregon

Contact: Steven Still (541/484-1125)

Objective: The objectives of the project are to: 1) conduct a program to identify electric utilities throughout the country for which EWEB's trademarked "The Bright Way to Heat Water" solar market development program has the potential to be a viable venture; 2) market the program to other utilities in a pilot implementation; and 3) determine the feasibility of a business venture in which EWEB would install solar water heaters and sell the energy produced by the systems.

Description: EWEB has been conducting its own "Bright Way to Heat Water" ™ solar water heating market development program for eight years. EWEB's contract with NREL involves the following tasks: 1) evaluation of "The Bright Way to Heat Water" program; 2) development of the business plan for marketing "The Bright Way to Heat Water" to other utilities; 3) pilot implementation of the marketing program; 4) determining the feasibility and profitability of an energy services venture in which EWEB would install (or have a solar dealer install) solar water heaters on homes and/or businesses and either lease the systems to the customers or sell them the energy delivered by the systems; and 5) formulation of a market development plan for implementing the ESCO venture (if feasibility is shown.)

Progress: EWEB has completed a critical analysis and evaluation of its "The Bright Way to Heat Water" program. The review of the program also included an analysis of the O&M problems that have been encountered with the five types of solar water heaters being offered in the program. EWEB has also completed the business plan for marketing "The Bright Way to Heat Water" program to other utilities. EWEB has identified over 100 utilities in the western U.S. that have profiles for which "The Bright Way to Heat Water" program is potentially viable. EWEB is currently engaged in pilot implementation of marketing "The Bright Way to Heat Water" to other utilities. EWEB has completed design, development, and production of the promotional materials being used in the pilot implementation.

Period: July 1998 – July 2000

		Funded	Cost-Share	Total
Amount:	FY98	$ 50,000	$310,000	$360,000

Monitor: Russell Hewett (303/384-7463)

Removing Codes, Covenants and Restrictions As Barriers To Solar Market Acceptance and Penetration

(Subcontract No. AXG-8-18479-01)

Contract Summary
December 1999

Contractor: **Florida Energy Office (FEO) / Florida Department of Community Affairs**
Tallahassee, Florida

Contact: James Tatum (850/488-2475

Objective: The objectives of this collaborative, cost-shared project are to: 1) formulate and conduct a project to address removal of codes, covenants, and restrictions (CC&Rs) as barriers to solar market acceptance in Florida, California, and Arizona; 2) develop a CC&R barrier removal strategy and action plan that can be made available for use in other states; and 3) evaluate the effectiveness of the Florida "SunBuilt" market development program in getting solar water heating accepted as a standard or optional feature in new homes in Florida.

Description: The project is a collaborative, cost-shared activity involving FEO, the NREL Solar Buildings Program, the NREL Photovoltaics Program, the Florida Solar Energy Research and Education Foundation (FlaSEREF), the Arizona Solar Energy Industries Association (ARISEIA) and the California Solar Energy Industries Association (CALSEIA). While the NREL subcontract is with FEO, FEO is using FlaSEREF to do the actual work, with ARISEIA and CALSEIA being subcontractors to FlaSEREF. The Florida "SunBuilt" program is also operated by FlaSEREF to educate homebuilders and buyers about the benefits of solar energy.

Progress: The contractors have formulated the CC&R barrier removal educational and familiarization program. The print materials to be used in the program have been designed and developed. FlaSEREF, ARISEIA and CALSEIA are in the process of identifying homeowner associations, associations of homeowner associations, homebuilder associations, and other organizations in their respective states that are targets for the educational program. In addition, they are working with such organizations to schedule training sessions. To date, actual training sessions have not yet been conducted and the evaluation of the effectiveness of the "SunBuilt" program has not been completed.

Period: September 1998 – December 1999

		Funded	Cost-Share	Total
Amount:	FY98	$ 70,000	$100,000	$170,000
	FY98 (NREL PV Program)	$ 30,000		$ 30,000
	Total Project	$100,000	$100,000	$200,000

Monitor: Russell Hewett (303/384-7463)

Utility Solar Hot Water Organization Utility Users Group Facilitator/Coordinator

(NREL Subcontract No. TAR-8-17686-01)

Contract Summary
December 1999

Contractor: **ENSTAR**
DePere, Wisconsin

Contact: Tad ("Chip") Bircher (920/433-5518)

Objective: The objective of this contract is to provide support for facilitating and coordinating activities being conducted annually by the Utility User Group of the Utility Solar Hot Water Initiative (USH2O).

Description: The activities associated with the subcontract are as follows: 1) planning, arranging, and facilitating monthly teleconference meetings of the USH2O coordinating committee as well as generating and disseminating the minutes of the meetings; 2) identifying utilities that have the potential to consider initiating solar water heating business ventures and familiarizing them with the technology as well as with what other utilities are doing with the technology; 3) providing customized economic feasibility support to utilities investigating the implementation of solar ventures; and 4) looking for opportunities for USH2O participation in the Million Solar Roofs Initiative and then coordinating actual planning and participation.

Progress: The coordinating committee, facilitated by the contractor, conducts a monthly teleconference meeting relating to USH2O activities. The contractor also maintains a database of utilities that conduct solar water heating programs as well as utilities that have expressed interest in implementing such programs. Approximately 10 utilities have so far expressed an interest in solar water heating ventures and have been supported by ENSTAR. ENSTAR has also generated a booklet *"Utility Opportunities in Solar Water Heating: Green…and Profitable"* that describes the potential advantages of solar as a business venture for utilities. The contractor keeps abreast of solar technology success stories, government programs, and initiatives that have the potential to make solar an attractive offering for utilities and disseminates such information to various utilities.

Period: October 1997 – September 2000

		Funded	Cost-Share	Total
Amount:	FY97	$ 50,000		$ 50,000

Monitor: Russell Hewett (303/384-7463)

Solar Buildings Program Technical and Programmatic Support

(NREL Consulting Agreement No. CXL-9-29005-01)

Contract Summary
December 1999

Contractor: **Western Renewables Group**
Mission Viejo, California

Contact: Les A. Nelson (949/586-2470)

Objective: The objectives of this activity are to: 1) provide technical and programmatic support to the Solar Buildings Program from the perspective of the solar industry; and 2) provide support to the Program in communications and liaison with the solar industry and other stakeholders.

Description: The activity involves the following: 1) providing technical and programmatic support to the Program with respect to solar buildings activities outside of NREL and Sandia; 2) providing support in the formulation of strategies, action plans, and roadmaps for putting solar water heating on an accelerated path to market acceptance and penetration; 3) servicing as a liaison between the Program and the nation's solar industry; and 4) providing support for the Program with respect to participation in the Million Solar Roofs Initiative.

Progress: The consultant has worked vigorously to greatly improve communications and trust between the Program and the nation's solar thermal industry. Each year, the consultant has orchestrated a formal, well-attended forum that provides the solar industry with the opportunity for input into the planning of the Program. The consultant also serves as a member of the Program's management team, serves on the USH2O planning committee ,and has provided ongoing technical and administrative support to the Program's U. S. Markets Assistance Task. In addition, the consultant provides ongoing support to the Program with respect to participation in the Million Solar Roofs Initiative. In FY2000, in addition to the above-mentioned activities, the consultant will plan and manage a peer review of the Program involving an array of outside stakeholders.

Period: November 1997 – September 2000

		Funded	Cost-Share	Total
Amount:	FY97	$ 19,000		$ 19,000
	FY98	$ 50,000		$ 50,000
	FY99	$ 75,000		$ 75,000
	Total Project	$144,000		$144,000

Monitor: Russell Hewett (303/384-7463)

Development of Markets for Solar Water Heating Systems for Buildings Applications

(DOE Cooperative Agreement No. DE-FC36-98GO10355)

Contract Summary
December 1999

Contractor: **Corporation for Solar Technology and Renewable Resources (CSTRR)**
Las Vegas, Nevada

Contact: Robert LeChevalier (702/270-2072)

Objective: The objectives of the project are to: 1) identify promising potential, sustainable markets for solar water heaters in the new homes construction industry; 2) develop an innovative, creative strategy and action plan for marketing solar systems to new home buyers; 3) show proof-of-concept of the market development plan by implementing it on a pilot basis; and 4) package and make the market development plan available as a "validated" model to other homebuilders (if it is successful).

Description: The homebuilder participating in the project is the Las Vegas Division of Pulte Homes. The project involves the following activities: 1) selection of the housing developments in which solar will be offered (as an option); 2) establishment of formal business partnerships with solar suppliers; 3) determination of how solar will be integrated into Pulte's home building operations; 4) formulation of the market development strategy and action plan; 5) implementation of the market development plan on a 12-month pilot implementation program; and 6) systematic evaluation of the pilot program and the market development plan.

Progress: CSTRR has selected Sun Systems, Inc. (Scottsdale, AZ) and Heliodyne, Inc. (Richmond, CA) as its solar water heater suppliers. Sun Systems and Heliodyne staffs have conducted solar familiarization and installation training programs for the Pulte contractors. CSTRR and Pulte have completed development of the promotional materials to be used by the Pulte sales staff in marketing solar. CSTRR and Pulte have also completed development of the market development plan for marketing solar systems to homebuyers. Solar water heaters have been installed on four model homes at Pulte's Stallion Mountain project in Las Vegas. The project is now at the point that the 12-month pilot implementation of the business development plan is to be initiated.

Period: September 1998 – January 2000

		Funded	Cost-Share	Total
Amount:	FY98	$182,900	$297,500	$480,400

Monitor: Robert Martin/DOE Golden Field Office (303/275-4763)

Development of Markets for Solar Water Heating Systems for Buildings Applications

(DOE Cooperative Agreement No. DE-FC36-98GO10357)

Contract Summary
December 1999

Contractor: **Tucson Coalition for Solar (TCS)**
Tucson, Arizona

Contact: Charles DeCorse (520/745-3251)

Objective: The objectives of the project are to: 1) identify promising potential, sustainable markets for solar water heaters in the new homes construction industry as well as for existing homes; 2) develop innovative, creative strategies and action plans for marketing solar systems to homeowners and new home buyers; 3) show proof-of-concept of the market development plans by implementing them on a pilot basis; and 4) package and make the market development plans available as "validated" models to other homebuilders (if they are successful).

Description: The partners with TCS in the project are the homebuilders who are constructing homes in the new, planned community of Civano in Tucson, Arizona as well as Tucson Electric Power and Venture Catalyst. The plan is to offer solar systems as a standard feature in the approximately 2,600 homes to be built in Civano over the next 10 years. In addition, TCS is conducting efforts to get solar systems installed in existing homes and government buildings. The project involves the following activities: 1) selection of the housing developments in which solar will be offered; 2) establishment of formal business partnerships with solar suppliers; 3) determination of how solar will be integrated into the homebuilders' operations; 4) formulation of the strategies for marketing solar to new home buyers and to existing homeowners; 5) implementation of the market development plans on a 12-month pilot basis; and 6) systematic evaluation of the pilot program and the market development plans as well as a determination of the lessons learned.

Progress: In Civano, the homebuilders have completed selection of their solar suppliers and have worked out the solar installation process. The business plan for marketing solar has been completed. In addition, the promotional materials to be used in marketing solar have been developed. New home sales staff has been given solar training. All of the homebuilders participating in developing Civano are putting solar in the homes as a standard feature. To date, 40 solar installations have been completed. With respect to developing markets for solar in existing homes and in new home developments outside of Civano, TCS is conducting systematic familiarization and promotional efforts targeted at homebuilders, architects, and homeowners. Solar water heaters have been placed in Spring Home Show homes and Habitat for Humanity homes to showcase and promote solar. The goal in the pilot implementation efforts is to achieve 141 solar installations

Period:	September 1998 – January 2000			
		Funded	Cost-Share	Total
Amount:	FY98	$135,000	$269,529	$404,529

Monitor: Robert Martin/DOE Golden Field Office (303/275-4763)

Development of Markets for Solar Water Heating Systems for Buildings Applications

(DOE Cooperative Agreement DE-FC36-98GO10356)

Contract Summary
December 1999

Contractor: **Vermont Energy Investment Corporation (VEIC)**
Burlington, Vermont

Contact: David G. Hill (809/658-6060 Ext. 34)

Objective: The objectives of the project are to: 1) develop innovative, creative strategies and action plans for marketing solar water heaters in existing and new homes in the northeast region of the U.S.; 2) develop a business plan for marketing solar systems to existing homeowners and new home buyers; 3) show proof-of-concept of the market development plan by implementing it on a pilot basis; and 4) package and make the market development plan available as a "validated" model to other organizations (e.g., utilities) if it is successful.

Description: VEIC partners in the project are the solar distributor Solar Works, Inc. and the Vermont Department of Public Service. The project involves the following activities: 1) conducting market research to determine homeowner and homebuyer interest and preferred features in solar systems; 2) development of screening and site assessment protocols and tools for identifying homes (new and existing) for which solar systems would be viable; 3) identification of options for financing solar systems as well as any financial incentives that could make them economically attractive; 4) formulation of the business plan to be used to market solar systems; 5) design, development, and production of promotional materials to be used in marketing solar systems; 6) implementation of the market development plan on a 10-12 month pilot basis; and 7) evaluation of the of the pilot program and the market development plan as well as a determination of the lessons learned.

Progress: VEIC has completed the marketing research studies as well as the development of the screening and site assessment tools for determining whether or not solar systems might be economically viable for homeowners and homebuyers. VEIC has also completed development of the business plan for marketing solar systems as well as the development of the promotional materials for the pilot implementation program. VEIC has also initiated a systematic market-conditioning program in the major urban areas in Vermont. Pilot implementation is in progress. The goal is to achieve 12 solar installations. To date, no installations have resulted.

Period: September 1998 – January 2000

		Funded	Cost-Share	Total
Amount:	FY98	$ 72,827	$176,369	$249,196

Monitor: Robert Martin/DOE Golden Field Office (303/275-4763)

Development of Markets for Solar Water Heating Systems for Buildings Applications

(DOE Cooperative Agreement DE-FC36-98GO10358)

Contract Summary
December 1999

Contractor: **Wisconsin Public Service (WPS)**
Green Bay, Wisconsin

Contact: Mary L. Thorne (920/433-7676)

Objective: The objectives of the project are to: 1) develop innovative, creative strategies and action plans for marketing solar water heaters in new homes in the northern regions of the U.S.; 2) develop a business plan for marketing solar systems to existing homeowners and new home buyers; 3) show proof-of-concept of the market development plan by implementing it on a pilot basis; and 4) package and make the market development plan available as a "validated" model to other organizations (e.g., utilities) if it is successful.

Description: WPS's partners in the project are the Energy Center of Wisconsin, Energy Alliance Group, Hagler Baily, and the Wisconsin Energy Bureau of the Wisconsin Department of Administration. The project involves the following activities: 1) conducting marketing research to determine homeowner and homebuyer interest and preferred features in solar systems; 2) development of specifications for a "standard" solar water heater that WPS will market as well as selection of the solar supplier; 3) conducting installation training for plumbers and others that would be involved in installing solar water heaters; 4) formulation of the business plan to be used to market solar systems; 5) design, development, and production of promotional materials to be used in marketing solar systems; 6) implementation of the market development plan on a 10-12 month pilot basis; and 7) evaluation of the of the pilot program and the market development plan as well as a determination of the lessons learned.

Progress: WPS has completed the marketing research studies to determine consumer interest in solar systems. WPS has selected Heliodyne as its supplier of the "standard" solar water heater that it will be offering. WPS conducted a formal installation training workshop for eight plumbers that would install the solar systems in new homes. WPS has also completed development of the business plan for marketing solar systems as well as the development of the promotional materials for the pilot implementation program. The goal is to achieve 15 solar installations. To date, at least eight homebuyers have expressed "strong interest" in having solar installed in their new homes and one solar system has been installed.

Period: September 1998 – January 2000

		Funded	Cost-Share	Total
Amount:	FY98	$116,754	$261,128	$377,882

Monitor: Robert Martin/DOE Golden Field Office (303/275-4763)

Development of Markets for Solar Water Heaters in the New Single Family Homes and Manufactured Homes Construction Industries

(NREL Subcontract No. AAD-0-29465-02)

Contract Summary
March 2000

Contractor: **American Dream Builders, Inc. (ADB)**
Naples, Florida

Contact: James McCord, President (941/263-9494)

Objective: The objectives of the project are to: 1) identify promising potential, sustainable markets for solar water heaters in the new homes construction industry; 2) develop an innovative, creative market development/business development strategy and action plan for marketing solar to new home buyers; 3) show proof- of-concept of the market development/business development strategy and action plan by implementing it on a pilot basis; and 4) package and make the market development/business development strategy and action plan available as a "validated" model to other home builders (if it is successful).

Description: American Dream Builders has selected Thermal Conversion Technology (a solar equipment manufacturer) and Eco-$mart as its solar partners in the project . In addition, the Florida Energy Office of the Florida Department of Community Affairs will participate by making the resources of its "SunBuilt" solar promotional program available to American Dream Builders. The "SunBuilt" program is being conducted for the Florida Energy Office by the Florida Solar Energy Research and Education Foundation (FLaSEREF). The project involves the following activities: 1) selection of the housing developments in which solar will be offered (as an optional or standard feature); 2) establishment of formal business partnerships with solar suppliers; 3) determination of how solar will be integrated into ADB's home construction operations; 4) formulation of the market development/business development strategy and action plan for marketing solar; 5) implementation of the market development/business development strategy and action plan on a 12-month pilot implementation program; and 6) systematic evaluation of the pilot implementation program and the market development/business development strategy and action plan and determination of lessons learned.

Progress: This solar water heating market development project started in earnest in January 2000. ADB selected Thermal Conversion Technology (Sarasota, FL) to be its solar supplier. They made the decision to focus on Integrated Collector Storage (ICS) solar water heaters as the solar system to be offered. ADB has selected Eco-$mart (Sarasota, FL) to: 1) provide solar-specific technical support; 2) provide solar installation training for its trades contractors; and 3) provide support in designing and developing solar promotional materials. In addition, ADB is focussing its solar efforts at new home buyers with limited resources (i.e., first-time-buyer/affordable homes market). Solar is being offered two ways: 1) as a stand-alone option that costs $2999; and 2) as part of an energy conservation "EnergyStar" bundle, which also includes an upgraded air conditioner, upgraded duct work, ceiling fans, a programmable thermostat, and independent testing

and verification of the reduced energy load. The bundle is being offered as an option costing $3990. ADM is reporting that 20% of their new home buyers are opting for the EnergyStar bundle.

Period: December 1999 – July 2001

		Funded	Cost-Share	Total
Amount:	FY99	$ 89,200	$120,780	$209,980

Monitor: Russell Hewett (303/384-7463)

Solar Company/Manufactured Homes Builder Partnership for Solar Markets Development

(NREL Subcontract No. AGX-8-18619-01)

Contract Summary
December 1999

Contractor: **Sun Systems, Inc. (SSI)**
Scottsdale, Arizona

Contact: Thomas Bohner (480/998-5858)

Objective: The objectives of the project are to: 1) develop an innovative strategy and action plan for marketing solar water heaters in the manufactured homes industry; 2) show proof-of-concept for the market development plan by implementing it; 3) package and make the market development plan available as a "validated, risk-minimized" model to other manufactured home builders (if the project is successful); and 4) formulate and evaluate engineering designs for solar collectors and the associated piping in which the collectors would be perceived as being an integral part of the roof of the home, as opposed to something "hung" on the roof.

Description: The partner with Sun Systems in the project is Cavco Industries, a subsidiary of Centex Homes, and one of the nation's largest builders of manufactured homes. The project involves the following activities: 1) establishment of a formal business partnership with Cavco Industries in which Cavco will offer solar water heaters as a standard or optional feature in manufactured homes and the systems will be installed on the homes while the homes are being assembled in the factory; 2) design and engineering of an ICS solar water heater specifically for manufactured homes as well as identification of the preferred approach for installing the systems on the homes while the homes are being assembled in the factory; 3) securing an SRCC rating for the manufactured homes ICS system; 4) formulation of the business plan for marketing solar to manufactured home buyers; 5) implementation of the business plan in a 10-12 month pilot implementation program; 6) systematic evaluation of the pilot program and the business development strategy as well as a determination of the lessons learned; and 7) formulation of aesthetically-pleasing designs for roof-mounted solar collectors for single-family homes.

Progress: Sun Systems and Cavco Industries have established the working partnership in which Cavco will offer Sun Systems' solar water heaters as an option in its manufactured homes. Design and engineering of the ICS solar water heater that will be marketed to homebuyers have been completed. Sun Systems and Cavco have determined the preferred approach for installing the solar water heaters on the homes while the homes are being assembled in the factory. The system has also been submitted to SRCC for evaluation and rating. However, the ICS system uses CPVC for the piping – a material for which SRCC has no evaluation and rating experience. This has resulted in Sun Systems and SRCC having to work together (with technical support from Sandia) to address all issues about the piping of concern to SRCC. In turn, this has slowed the planned pace for the project. Sun Systems and Cavco have completed development of the market development plan that will guide the 12-month pilot implementation. In addition, Sun Systems has completed development of the promotional materials that will

be used by the manufactured home sales personnel to market solar. Sun Systems has also completed development design concepts for roof-mountable solar collectors that are aesthetically pleasing. Consequently, once the ICS system (with CPVC piping) is approved by SRCC, Sun Systems and Cavco are ready to initiate the pilot implementation program immediately. The goal in the pilot implementation efforts is to achieve at least 50 solar installations.

Period: November 1998 – March 2001

		Funded	Cost-Share	Total
Amount:	FY98	$110,000	$150,000	$260,000

Monitor: Russell Hewett (303/384-7463)

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