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Low-Cost Solar Domestic Hot Water Systems for Mild Climates

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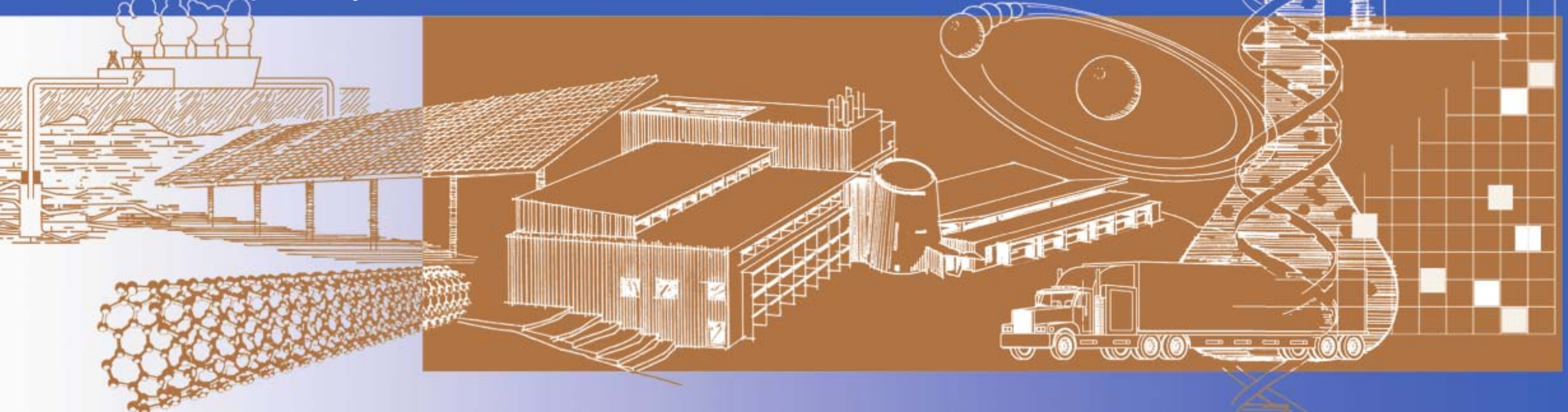

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ABSTRACT

In FY99, Solar Heating and Lighting set the goal to reduce the life-cycle cost of saved-energy for solar domestic hot water (SDHW) systems in mild climates by 50%, primarily through use of polymer technology. Two industry teams (Davis Energy Group/SunEarth (DEG/SE) and FAFCO) have been developing un-pressurized integral-collector-storage (ICS) systems having load-side heat exchangers, and began field-testing in FY04. DEG/SE's ICS has a rotomolded tank and thermoformed glazing. Based upon manufacturing issues, costs, and poor performance, the FAFCO team changed direction in late FY04 from an un-pressurized ICS to a direct thermosiphon design based upon use of pool collectors. Support for the teams is being provided for materials testing, modeling, and system testing. New ICS system models have been produced to model the new systems. A new ICS rating procedure for the ICS systems is undergoing testing and validation. Pipe freezing, freeze protection valves, and overheating have been tested and analyzed.

1. Objectives

The main goal for DOE's Solar Heating and Lighting subprogram is to reduce the cost of saved energy (COSE) for SDHWS by at least 50%. The objective of this work is to develop systems meeting this goal for passive systems suitable for mild climates. Costs include hardware, installation, marketing, and O&M [2]. In today's "retrofit" market, inherent inefficiencies and a moribund market lead to high installation overhead and marketing costs. To focus the COSE metric on reduction of the hardware and installation costs, the cost analyses are done in the context of "new construction," assuming high volumes as in [2,3]. COSE for current technology is ~10.2 ¢/kWh, giving a goal of ~5.1 ¢/kWh.

2. Technical Approach

The cost of saved energy is the ratio of costs (1^{st} cost + present value of O&M costs) to discounted energy savings. The approach here focuses on cost reductions, rather than performance increases. First cost, installation, and O&M costs are reduced through two related strategies: 1) use of polymer materials and manufacturing methods, and 2) product redesign aimed at part count reduction and simplified installation.

The development process is structured in three stages: conceptual design, engineering design, and product development. Conceptual design lays out and evaluates cost and performance of design alternatives with bench-top testing to resolve uncertainties. Five teams were chosen initially, down-selected to two teams at the end of conceptual development. Engineering design tests small and/or full-scale prototypes, with redesign(s). Both "torture tests" and field tests are included. Product design combines resolution of field-testing issues and redesign(s) for lowest-cost manufacturing. Both teams entered product design during FY04. Because of the change, FAFCO is attempting to shorten development of its new designs through use of existing pool collector technology, rapidly progressing through conceptual and engineering design. This has led to issues with designs. Both teams plan to begin product offers near the end of 2005.

The key issue in use of low-cost polymer materials and manufacturing is durability. Thus, accelerated testing of proposed materials is being done at NREL, for both glazings and absorbers as in [4]. Because the new system types have features not previously modeled, new ICS and thermosiphon models have been developed at NREL to accommodate them. The new models are integrated into a new rating procedure [5,6]. Pipe freezing [7], freeze-protection valves [8], and overheating [9] have been analyzed.

3. Results and Accomplishments

The DEG/SE system [10] is shown in Fig. 1. The system has been performing somewhat above expectation in field trials. Expectation of saved energy is based upon a standard draw volume and profile, and the high-draw volume and dispersed profile of the residences chosen yield increased performance relative to the standard case. The system was subjected to a variety of "torture tests", including wind uplift, salt corrosion, water spray, hail impact, rough handling, panel creep, and wet/dry stagnation. The wind uplift test led to redesign of the glazing-tank clips. Unsatisfactory rate of leaks upon rotomolding has led to a revised mold design that has apparently corrected the leaks.

The new FAFCO thermosiphon system [11] is shown in a CAD perspective in Fig. 3. The collector is a glazed pool collector. A direct, open loop version with collector and storage at line pressure and with storage tubes alongside the collector is shown. This version suffers dramatically for standard draw profiles from reverse thermosiphoning at night. Performance loss compared to a version with storage above the collector is estimated at 50%, because of giving up on morning and late-evening loads. The performance estimates will be grounded in simulation once the new models, which allow reverse thermosiphoning, are finished and validated. Once prototypes are completed, tests will be conducted to calibrate the model, similar to the processes discussed in [5].

Table 1. Costs and COSE for conventional and new systems

	Conven-tional ICS	DEG-SE ICS	FAFCO Ther-mosiphon[1]
Collector	$800 [2]	$518	$200
Storage	-	-	$150
BOS	$200	$175	$150
Installation	$500	$225	$300
Marketing[2]	$375	$230	$200
O&M			
Efficiency[3,4]	30%	28%	13%/26%
COSE[5]	10.2	5.5	10.4/5.3
% Reduction[4]	-	46%	-2%/48%

[1]All costs and performance are estimates
[2]Marketing is 25% of the total hardware + install cost
[3]Efficiency = (annual savings)/(annual incidence)
[4]The two numbers in the table for FAFCO correspond to side/top location of storage, respectively
[5]COSE is given in units of ¢/kWh

Figure 1. The DEG/SE ICS unit on a roof in San Diego.

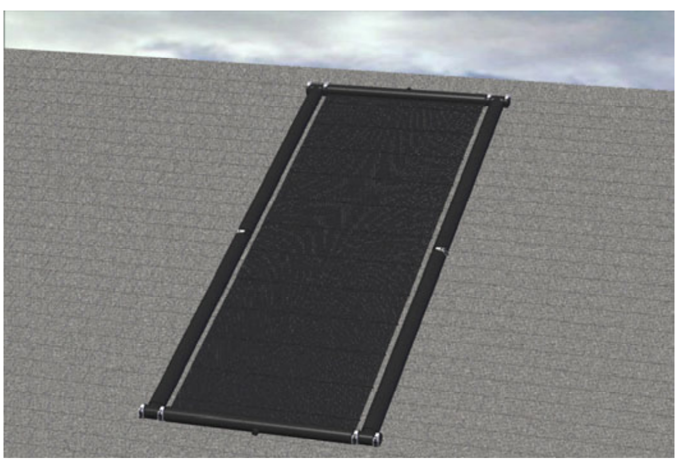

Fig. 2. The FAFCO thermosiphon design, shown with storage tubes alongside the collector.

Projected first cost and COSE for both systems are shown in Table 1. The cost and performance numbers for the DEG/SE system are reasonably well defined. The COSE reduction is just under 50%. The numbers for the FAFCO system are currently not well defined, as real systems have not yet been credibly tested for annual performance projections. Two efficiency/COSE numbers are given for the FAFCO system, corresponding to storage alongside the collector and storage above the collector (16% and 32%, respectively). The 26% figure is a simulation result [3], whereas the 13% number is estimated at 50% of the performance of the top-storage case. The side storage system does not perform well, and the top storage system might meet program goals.

Ref. [4] shows that a polycarbonate glazing with a Korad film coating will perform upwards of 20 years without yellowing or mechanical degradation, a major outcome of the materials-testing work. The absorber materials for both ICS systems experienced embrittlement and expected problems under extended dry stagnation, but worked well under no-load, wet stagnation.

4. Conclusions

The DEG/SE system is well-defined and undergoing field tests favorably. It appears that leak problems have been resolved. The FAFCO team recently changed their concept, and significant work remains. However, the concept appears to have good potential and is a good match with FAFCO's pool collector manufacturing experience. Both systems appear capable of meeting the DOE program goal of 50% cost reduction, within several percentage points. A film coating for polycarbonate glazings has been identified that gives promise of greater than 20-year lifetime.

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