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Cold-Climate Solar Domestic Hot Water Systems Analysis

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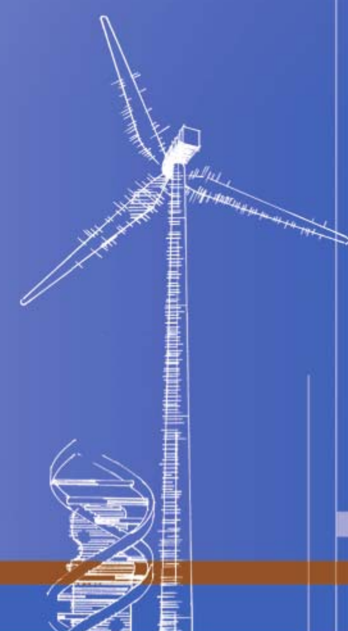

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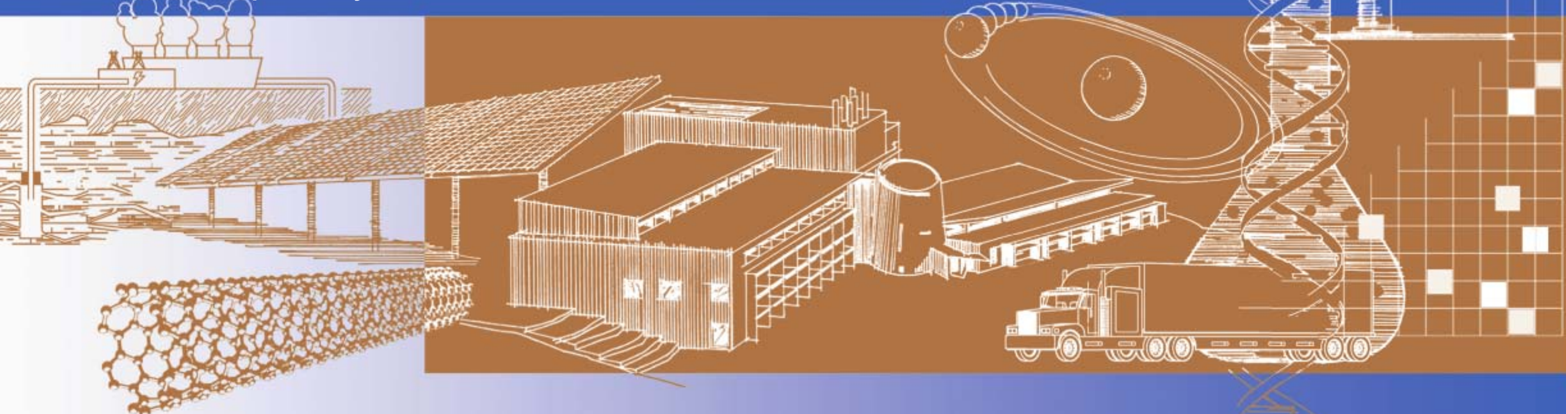

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Cold-Climate Solar Domestic Hot Water Systems Analysis

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ABSTRACT

The Solar Heating and Lighting Sub-program has set the key goal to reduce the cost of saved energy [C_{sav}, defined as (total cost, $)/(total discounted savings, kWh_thermal)] for solar domestic water heaters (SDWH) by at least 50%[1]. To determine if this goal is attainable and prioritize R&D for cold-climate SDWH, life-cycle analyses were done with hypothetical lower-cost components in glycol, drainback, and thermosiphon systems. Balance-of-system (BOS, everything but the collector) measures included replacing metal components with polymeric versions and system simplification. With all BOS measures in place, C_{sav} could be reduced more than 50% with a low-cost, selectively-coated, glazed polymeric collector, and slightly less than 50% with either a conventional selective metal-glass or a non-selective glazed polymer collector. The largest percent reduction in C_{sav} comes from replacing conventional pressurized solar storage tanks and metal heat exchangers with un-pressurized polymer tanks with immersed polymer heat exchangers, which could be developed with relatively low-risk R&D.

1. Objectives

Objectives for the project were to:

1) Establish a baseline of available cold climate systems
2) Investigate possible improvements to the system, and determine the best opportunities for reducing C_{save} by at least 50%.

2. Technical Approach

Computing C_{save} involves computing system cost and performance. Performance modeling was done with the well-known simulation tool TRNSYS. Total cost C_{total} can be broken down into costs for hardware, installation, marketing, and O&M. The first three costs compose the first cost to the homeowner. O&M costs are the present value of future time-series costs calculated statistically. Costs depend heavily on the market scenario chosen. A "new construction" scenario was used here, with a builder markup of 25%. Component prices were based upon: 1) for existing components, the lowest available quote from industry suppliers and 2) for proposed components, price quotes on "similar" components or detailed cost modeling.

Three system types were chosen: glycol, drainback, and indirect thermosiphon. Component variations considered are shown in Table 1. Assumed collector costs are shown in Table 2. BOS variations included an un-pressurized polymer tank with immersed polymer heat exchanger(s), polymer piping, integrated valve package, and (for glycol and drainback) solar-side pump removal. Costs assumed for the BOS variations are given in Table 3.

Table 1: Component Variations

Component	Baseline	Variation(s)
***All types**:*		
Collector	Selective	Non-selective; glazed (selec./non-selec.), and unglazed polymer
Storage	Pressurized	Un-pressurized with load- and collector-side heat exchanger
Heat exchanger (HX)	Metal/copper	Polymer tube bundle
Piping	Hard copper	Polymer tubing
Valves	Piece-by-piece	Integrated package
Glycol/drainback only		
Storage-side pump	9/10W pump	Remove pump (use thermosiphon)

Table 2. Collector Cost

Collector*	Cost
Selective metal-glass	$500
Nonselective metal-glass	$450
Polymer- selective	$250
Polymer- non-selective	$200
Polymer- unglazed	$100

* Collectors are all 40 ft^2

Table 3: BOS Cost Reduction Measures

BOS Measure	Savings (+) from the base case, in order: Hardware/ Install*/O&M/Total **.
Glycol only:	
Remove load-side pump	$82/$22/ $73/$220
Polymer tank/HX	$280/$74/$256/$761
Drainback only:	
Remove load-side pump, use polymer tank/HX	$562/$192$/358/$1,390
Thermosiphon only:	
Polymer tank, HX, piping	$400/$30/$542/$1,215
Glycol/Drainback:	
Polymer piping	$70/$284/$148/$553
All Systems:	
Valve package	-$25/$130$/0/$131

* Includes direct labor and consumables, and overhead/profit on installation of 100%/50%.
** Sum of savings from previous three categories, plus additional 25% savings from markup.

3. Results and Accomplishments

The cumulative changes in system first cost (hardware, installation, and builder markup) and system C_{save} from system variation are shown in Fig. 1 for glycol systems and Fig. 2 for thermosiphon systems. Results for the drainback system are also available[2]. The base case is the first system on the far left of each plot. The improvement made is given by the x-axis labels. Once an improvement in the BOS is introduced, that improvement stays in. For collector substitutions (starting after all BOS improvements), the collectors are swapped in/out from highest to lowest cost. With this ordering, costs always decrease going from the base case to the least-cost system on the far right. C_{save} decreases with the BOS improvements, as performance is not significantly impacted and costs decrease. For the collector substitutions, however, performance is decreased from the base case, except for the "selective polymer" collector, which is defined to have the same performance as the base-case collector.

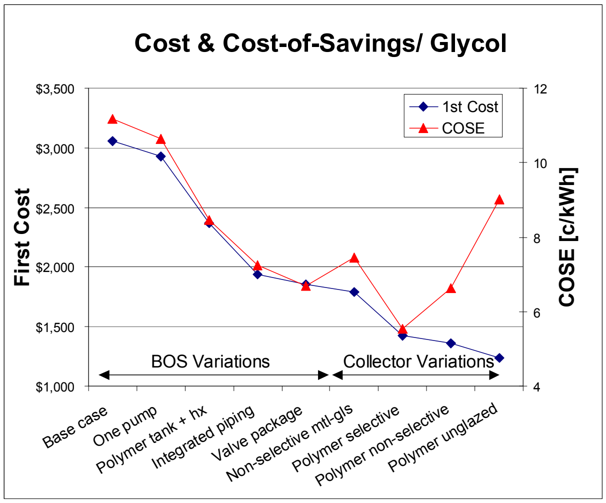

Fig. 1: First cost and C_{sav} for glycol systems.

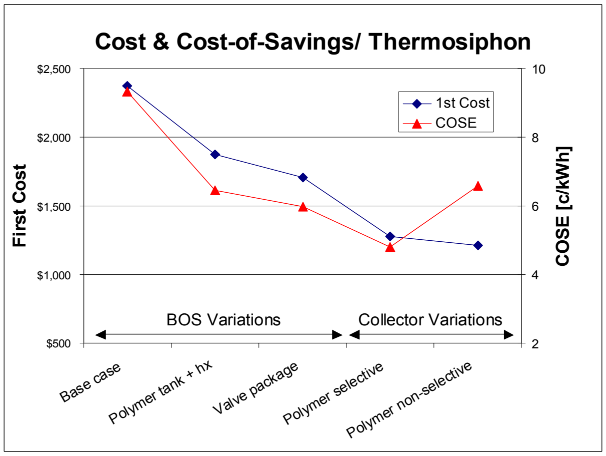

Fig. 2: First cost and C_{sav} for thermosiphon systems.

For the glycol system, the first cost decreased from ~$3,100 to ~$1,300. For the thermosiphon system, cost decreased from ~$2,400 to ~$1,200. The difference in cost between the pumpless thermosiphon and the glycol system is less than the difference in total cost of the pump, controller, and sensors, because, for the thermosiphon, the tank is more costly, the piping has to be freeze-protected, and the installation in the attic is more difficult.

In all cases, the lowest-cost system resulted with the (purely hypothetical) selective polymer collector (see Table 4). The polymer non-selective collector yielded about the same C_{sav} as the base-case selective collector (all BOS improvements present).

4. Conclusions

Table 4 compares improved glycol and thermosiphon systems to a baseline glycol system with installed cost of ~$3,059 and $C_{save,baseline}$ = 11.2 ¢/kWh. Percent reduction in C_{save} is relative to this system. First cost, C_{save}, and % reduction are given for base system, the system with all BOS improvements, and for the system with all BOS + the polymer selective collector. The program goal is to reduce C_{save} by at least 50%, to 5.6 ¢/kWh or lower. With only the BOS improvements hypothesized here, the reduction relative to the baseline is about 40% for glycol, 46% for the cold-climate thermosiphon. With all the BOS improvements and the selective polymer collector, the reduction is about 51% for glycol, 57% for a cold climate thermosiphon. It appears possible to meet the program saved-energy cost reduction goal, but only with successful BOS R&D (up to 46% reduction) or BOS and low-cost polymer collector R&D (up to 57% reduction).

Table 4: 1st Cost & Csav for 2 Cases

System:	Glycol[1]			Thermosiphon[1]		
	Base	BOS	BOS+	Base	BOS	BOS+
First cost	$3059	$1856	$1425	$2,377	$1706	$1275
C_{sav}[2]	11.2	6.7	5.5	9.3	6.0	4.8
% reduced[3]	0%	40%	51%	17%	46%	57%

[1]Three cases are given: Base=base case, BOS=all BOS changes, and BOS+=all BOS changes + selective polymer collector.
[2] C_{sav} units are (¢/kWh).
[3] The % reduction is relative to the base-case glycol system.

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