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# Cold-Climate Solar Domestic Hot Water Systems: Cost/Benefit Analysis and Opportunities for Improvement

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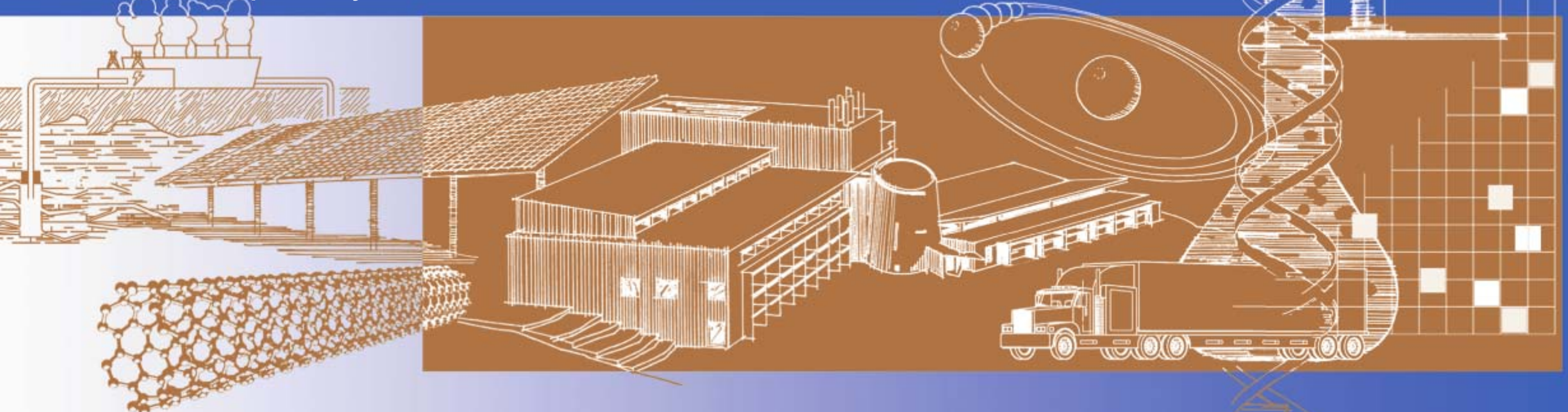

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# Cold-Climate Solar Domestic Hot Water Systems: Cost/Benefit Analysis and Opportunities for Improvement

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## ABSTRACT

To determine potential for reduction in the cost of saved energy (COSE) for cold-climate solar domestic hot water (SDHW) systems, COSE was computed for three types of cold climate water heating systems. For each system, a series of cost-saving measures was considered: 1) balance of systems (BOS): tank, heat exchanger, and piping-valving measures; and 2) four alternative lower-cost collectors. Given all beneficial BOS measures in place, >50% reduction of COSE was achievable only with selective polymer collectors at half today's selective collector cost. In all three system types, today's metal-glass selective collector achieved the same COSE as the hypothesized non-selective polymer collector.

## 1. Objectives

The main goal for DOE's Solar Heat and Light sub-program is reducing the cost of saved energy (COSE) for SDHW systems by at least 50% [1]. The objective of this work is to determine if this goal is realistic for cold-climate SDHW systems.

## 2. Technical Approach

Three system types are considered: glycol, drainback, and indirect thermosiphon. For cold climates, glycol and drainback are common, whereas the thermosiphon is relatively novel. COSE is estimated by simulating performance (at TMY2 sites) and estimating costs under a *new-construction* market scenario. With new construction, the installation is more efficient and marketing costs (at 25% of hardware+installation cost) are smaller, compared to the more-common "retrofit scenario" assumed in [2]. Costs are taken either as the "best-available" costs provided by manufacturers or as estimated from similar products, rather than as costs from detailed analysis of specific designs. Costs include direct materials (collector and balance-of-system (BOS) hardware), installation (labor, materials, overhead/profit), marketing, and O&M. Cost modeling framework and algorithms are detailed in [2]. When a component is varied, installation costs and O&M costs are varied accordingly, as in [3].

We define a series of hypothetical cost-reduction measures for each system type. As in Table 1, BOS variations include unpressurized polymer storage with immersed polymer heat exchangers, integrated polymer piping, and an integrated valve package. A variation specific to glycol systems is to eliminate the storage-side pump with a thermosiphon loop between heat exchanger and solar storage tank. Collector variations and assumed costs are given in Table 2.

Table 1. Some BOS Components and Assumed Cost

| Component | Description | Cost[1] |
|---|---|---|
| Metal Tank + heat exchanger | Conventional tank with external side-arm hx | \$460 |
| Polymer tank + heat exchanger | Unpressurized polymer tank with immersed polymer hx | \$180 |
| Integrated piping | Supply/return piping with integral insulation | \$25/100[2] |
| Valve package | Factory-assembled unit of all valves and sensors | \$200 |

[1] Direct cost only, does not include install costs or O&M
[2] \$1/ft for glycol and drainback, \$4/ft for thermosiphon

Table 2. Collectors, Properties, and Assumed Costs

| Collector | $F_r(\tau\alpha)_n$ [1] | $F_rU_l$ [1] | Cost |
|---|---|---|---|
| Metal-glass-selective | 0.779 | 4.77 | \$500 |
| Metal-glass-non-selective | 0.768 | 7.245 | \$450 |
| Polymer-selective[2] | 0.779 | 4.77 | \$250 |
| Polymer-non-selective | 0.739 | 8.216 | \$200 |
| Polymer-unglazed | 0.88-0.029*v | 10.24+4.69*v | \$100 |

[1] Taken from [4], except for unglazed data from [5].
[2] Taken as identical to the metal-glass selective collector.

## 3. Results and Accomplishments

The BOS enhancements do not *per se* affect system performance; their impact is on first cost only. Simulations were done for the four unique sets of collector parameters (selective polymer=selective metal-glass), for all three system types, except that the unglazed collector has not been done with the thermosiphon system because of convergence problems. Efficiency of the glycol system with the four collector parameter sets is shown in Fig. 1. The efficiency is ~constant for each collector, decreasing slightly with increasing site temperature. U.S. maps of savings, efficiency, and solar fraction for all systems/collectors can be found in [3], similar to Fig. 2.

Base case and the best two variations are shown in Table 3. With all cost-reducing BOS variations in place, the maximum reduction in COSE is obtained with the hypothetical selective polymer collector. In all three system types, the result with the non-selective polymer collector is about the same as with the base-case metal-glass selective collector.

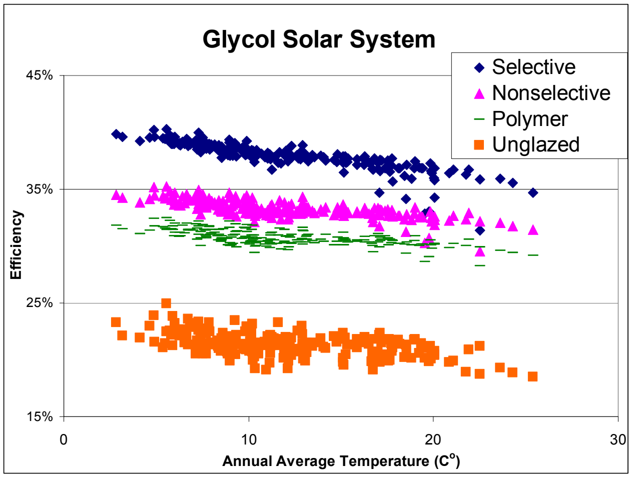


Fig.1. Efficiency (Savings/Incidence) for the glycol system with the four different sets of collector parameters.

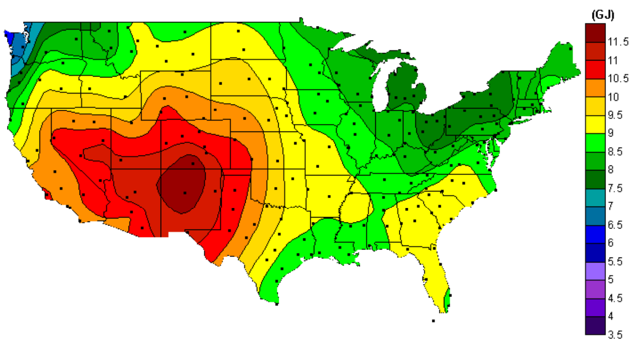


Fig. 2. U.S. Map of Glycol-selective annual savings.

Results for all the variations on the glycol system are shown in Figure 3. BOS variations are done first, followed by collector variations. Once a BOS measure is introduced, it remains for succeeding cases. BOS measures account for most of the COSE reduction. The non-selective metal-glass collector and the unglazed polymer collector are not effective measures because they increase COSE. Even though first costs are lowered, performance is lowered proportionally more. For all cases, only the use of the polymer collectors results in first cost under $1,500. For all three SDHW types, use of the non-selective polymer collector results in approximately the same COSE as the base-case selective metal-glass collector, but with lower first cost. For similar measures, the thermosiphon system always has the lowest COSE value by ~10%, because of elimination of the pump and controller needed in the two active systems.

Table 3. Base and Best COSE for Three System Types

| System | Glycol | | Drainback | | Thermosiphon | |
|---|---|---|---|---|---|---|
| | Base | Best2* | Base | Best2* | Base | Best2* |
| COSE (¢/kWh) | 11.2 | 5.5/6.3 | 11.8 | 5.2/6.3 | 9.3 | 4.8/6.6 |
| % Reduction2* | 50.5/40.7 | | 53.5/43.8 | | 57.0/46.4 | |

Note: Best2 and %Reduction2 cells give results for the two *best* cases: polymer-selective/polymer-non-selective. The COSE with today's selective metal collector is about equal to the COSE with the hypothesized polymer non-selective collector.

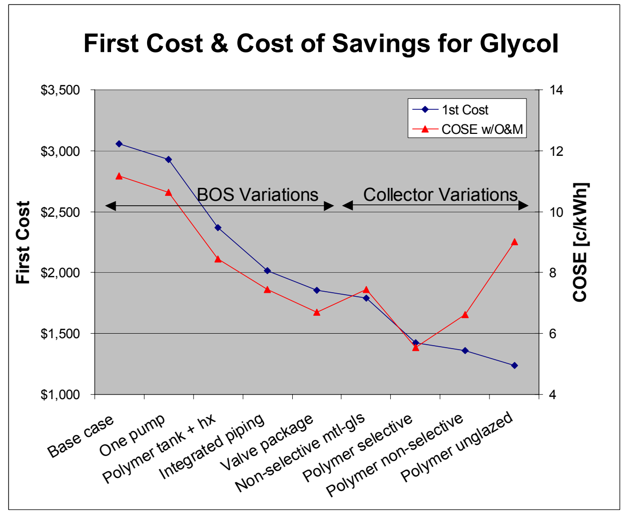


Fig. 3. First cost and COSE for the glycol system. COSE data are shown with/without O&M cost included.

## 4. Conclusions

COSE values have been generated for three system types, with BOS variations and five different collector types. The lowest COSE is with all BOS variations in place and use of a hypothetical selective polymer collector. Next-best COSE values were with use of a polymer non-selective or selective metal-glass collector. Polymer collectors made with commodity plastics can cause issues with overheating. Thermosiphon systems have the lowest COSE, but bring issues with pipe freezing and storage location.

## REFERENCES


[1] Solar Energy Technology Program Multi-Year Technical Plan. U.S. DOE/EERE, DOE/GO-102003-1775.

[2] J. Burch, J. Salasovich, C. Christensen, B. Lorand, and B. Scholten, "Cost-Benefit Modeling of Solar Domestic Hot Water Systems," *Procedures of the ASES 99 Solar Conference; ASES, Boulder, CO; June 1999.*

[3] J. Burch, T. Hillman, and J. Salasovich, "Cold Climate Solar Domestic Hot Water Systems: Cost/Benefit Analysis and Opportunities for Improvement," NREL TP-550-37012, October 2004.

[4] Directory of SRCC Certified Solar Collector Ratings. Available at http://solar-rating.org

[5] S.J. Harrison, D. McClenahan, V.H. Nielsen, "The Performance of Unglazed Solar Collectors," *Procedures of the 15th Annual Conference of the Solar Energy Society of Canada, Penticton, B.C., June 1989, pgs. 235-239.*


## MAJOR FY 2004 PUBLICATIONS

Burch, J., Salasovich, J., Christensen, C., and Thornton, J., "Geographical Variation in Performance of an Unglazed Solar System Meeting Water Heating and Space Conditioning Loads", 2004 ASES Conference Proceedings, ASES, Boulder, CO.

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