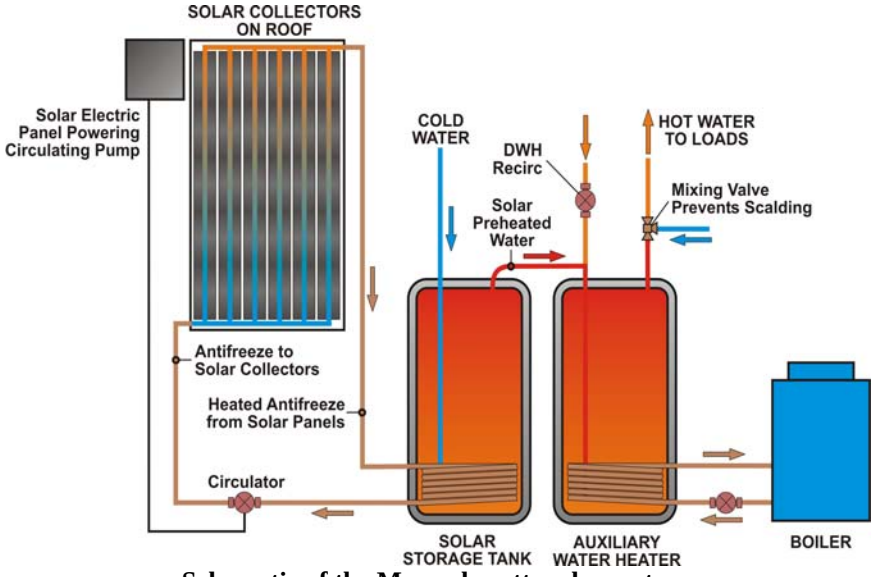
Cold-Climate Solar Thermal Systems

Steven Winter Associates collected detailed long-term performance data on two solar domestic water heating systems installed in cold climates, one in western Massachusetts and one in Wisconsin. The similarity of the systems as well as the homes' occupancy and water use made for interesting comparisons and lessons learned. Both systems are indirect, closed-loop systems (appropriate for cold climates) each with two 32-ft^2 flat-plate collectors on the roof and an 80-gallon storage tank in the basement. Both homes were occupied by 4-person families that consume 60-80 gallons of hot water per day.

Roof top solar collectors on the Massachusetts home.

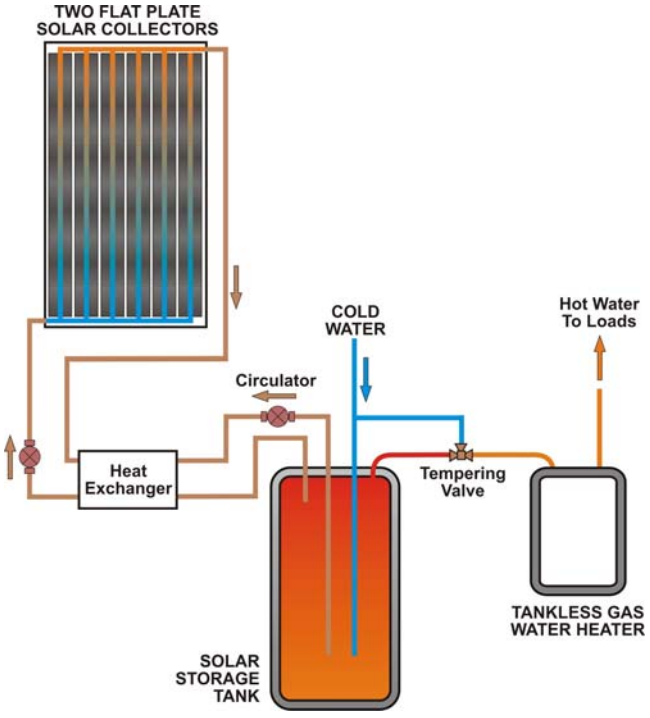
In 2003, Western Massachusetts Electric Company (WMECO) partnered with SWA to begin researching the benefits – both to the utility and to homeowners – of zero energy homes. As a preliminary effort, WMECO sponsored the construction of a solar home in Hadley, MA. The installed solar hot water system, shown schematically, uses PV control, a single DC circulator, and a heat exchanger within the basement storage tank. Auxiliary hot water is provided by the boiler and a separate indirect water heater.



Schematic of the Massachusetts solar system.

In conjunction with the Wisconsin Focus on Energy program, SWA facilitated the installation of a solar thermal water heating system at a prototype home built by Veridian Homes in 2004. The Wisconsin system is also an indirect system, but it differs from the Massachusetts system in that it has differential temperature control and a heat exchanger outside of the solar storage tank. The system has two AC circulators: one circulates a blend of 55% glycol and 45% water through the collectors, the other circulates potable water from the storage tank to the external heat exchanger. A tankless, natural gas water heater provides auxiliary water heating.

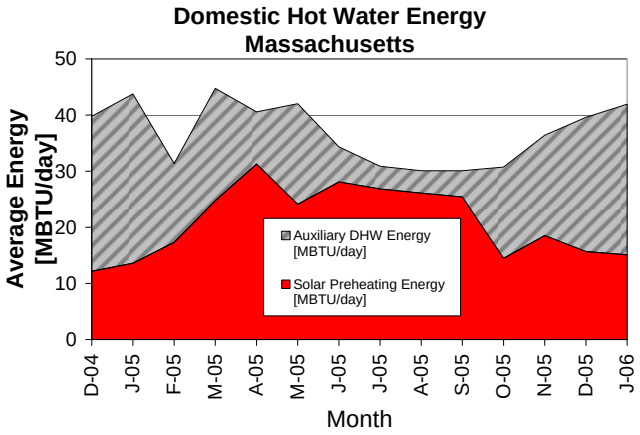
Auxiliary tankless gas water heater and solar storage tank in basement of Wisconsin home.



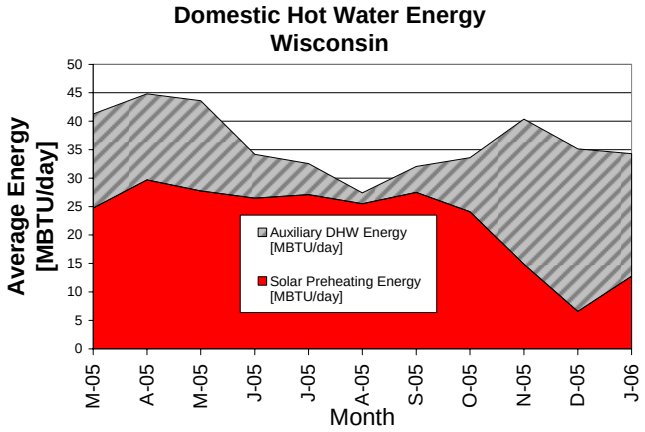
Schematic of the Wisconsin solar system.

ENERGY PERFORMANCE

The following graphs and table present the performance of the systems.



Domestic water heating energy provided by solar and auxiliary oil/biodiesel boiler in the Massachusetts home.



Domestic water heating energy provided by solar and auxiliary tankless gas heater in Wisconsin home.

SUMMARY OF SOLAR DOMESTIC HOT WATER PERFORMANCE

	Massachusetts (1 year)	Wisconsin (11 months)
Average Solar Fraction	61%	63%
Average Hot Water Use	64 gal/day	71 gal/day

MONITORING AS COMMISSIONING

Data collected from both systems revealed problems with the water heating systems that compromised overall efficiency.

In the Massachusetts home, a timer-controlled recirculating pump was installed to provide more immediate hot water to bathrooms. Although convenient for the homeowners, the data showed that the recirculation of hot water resulted in significant cooling of the indirect water heater. Even when the solar tank was hot, the oil boiler was often needed to reheat the indirect water tank because of the excessive recirculating losses.

Early evaluation of the Madison solar system under operation revealed a poorly configured tempering valve and significant overnight tank losses. The tempering valve was set too low; the valve tempered the water to near 100°F or cooler such that the auxiliary heater was required to fire during every hot water draw – even when solar tank water was well above 125ºF. The valve was adjusted in mid-July to deliver approximately 125°F and the solar tank was wrapped with insulation. Solar utilization increased substantially with these improvements.

Lessons Learned

Both cold climate, indirect solar thermal systems evaluated work well - providing over 60% of the water heating load in each home.

Commissioning of solar thermal systems is important for good operation. Without monitoring, the homes would be consuming considerably more fossil fuel for water heating. In Massachusetts, the monitoring revealed the increased thermal losses due to a recirculation system and timer-controlled recirculating pump. In Wisconsin, an inappropriate tempering valve setting resulting in excessive gas use was observed and corrected.

The variable hot water supply temperature that can occur with integrated solar/tankless systems is a design issue that has yet to be resolved. However, the extent this characteristic would be a consumer issue is not known.

Resources

"Cost, Design, and Performance of Solar Hot Water in Cold-Climate Homes." Proceedings of the American Solar Energy Society Annual Conference. July 2006.

"Design, Installation, and Performance of Solar Hot Water Systems in New Homes." Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings, August 2006.