# Well-Grounded Solar

## A versatile way to integrate solar thermal and geothermal heat pumps.

Two thermally based renewable energy technologies that grab many headlines these days are solar water heating and geothermal heat pumps. Both now enjoy the "favored status" of a 30% income tax credit from Uncle Sam, as well as numerous other rebates and credits at the state level.

Solar thermal systems and geothermal heat pump systems are both ways of capturing solar energy. The solar thermal system does it in real time, whereas the geothermal heat pump system, operating from a horizontal earth loop, extracts solar heat driven into the soil several months earlier. This time shift between when the energy is available and when it's needed allows combinations of solar thermal hardware and geothermal heat pumps to be complementary.

Take a look at the system schematic in Figure 1 (on page 15). It combines both solar thermal and geothermal heat pump subsystems into an overall system for space heating, space cooling and domestic water heating.

### Heating Mode

The primary heat source for space heating is the water-to-water geothermal heat pump. During the heating season it extracts low temperature heat from the earth loop, converts it to higher temperature heat and parks that heat in a well-insulated buffer tank.

When the heat pump is gathering heat from a horizontal earth loop, the fluid in the earth loop is at a relatively low temperature, especially during mid to late winter. In a Northern climate, this fluid may even be, at times, less than 32° F. In such systems the earth loop fluid is typically a 15% to20% solution of propylene glycol or other antifreeze.

A low-temperature distribution system delivers that heat when and where it's needed. A variable-speed, pressure-regulated circulator operates in response to the differential pressure across the headers. When a zone valve opens, the differential pressure across the headers attempts to decrease. The circulator senses this electronically and immediately increases its speed to restore the original (design) differential pressure.

The heat pump responds only to the temperature of the buffer tank, as monitored by an outdoor reset controller. The "responsibility" of the heat pump, based on this control scenario, is to keep the buffer tank temperature within a certain range of a target temperature whenever space heating may be required. The latter is calculated based on the settings of the reset controller and the current outdoor temperature. This approach minimizes the temperature of the buffer tank based on the prevailing conditions. In doing so, it improves both the heating capacity and coefficient of performance of the heat pump. Figure 2 shows an example of how the reset line of such controller could be set for a low-temperature distribution system.

### Cooling Mode

A similar operating mode is used for chilled water cooling. The heat pump chills the buffer tank and dissipates the absorbed heat to the earth loop. Chilled water flow is controlled by a second variable-speed, pressure-regulated circulator in response to zone valves on each chilled water air handler. The temperature of the buffer tank is now likely to be controlled by a setpoint device that keeps the water in the range of 45° F to 60° F whenever the cooling mode is active.

This configuration works well provided the building does not require heating and cooling within a short time of each other. It's obviously not very efficient to heat the buffer tank to supply heat in the morning and then cool it down to supply cooling that afternoon.

There are climates where heating is required in the morning, followed by a need for cooling in the afternoon. In such cases, one operating mode has to take precedence during swing seasons, or unusual weather conditions, until the system settles into a stable mode for the duration of the season. Another more costly and complex solution is to design the system with two buffer tanks -- one for heated water and the other for chilled water.

### Solar Assist

The solar subsystem shown in Figure 1 allows for two operating modes:

a. The solar heat collected is delivered to the DHW storage tank through the tank's internal coiled heat exchanger.

b. The solar heat is delivered to the earth loop through the brazed-plate heat exchanger.

If the sun is out, and the domestic water temperature is lower than some limit (say 140° F), the diverter valve routes the fluid leaving the collector through the tank's internal coiled heat exchanger.

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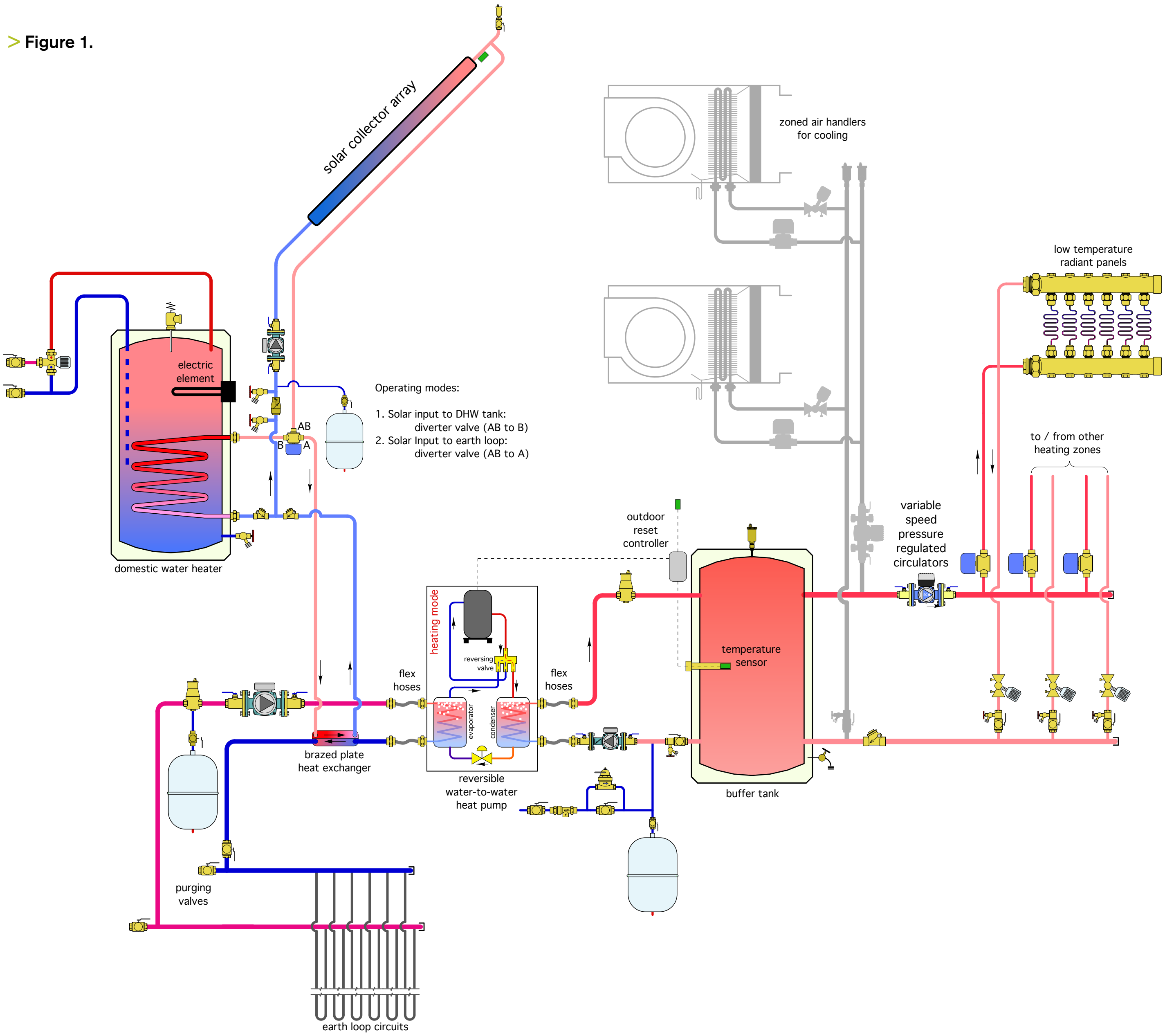
If the tank reaches the upper limit, and the sun is still shining, the diverter valve would reroute flow from the collector array to a brazed-plate heat exchanger in the earth loop. Connecting the collectors to the earth loop forces them to operate at a relatively low temperature, perhaps just a few degrees above that of the earth loop fluid. Under this operating mode, the collector array is partially unloading the earth loop.

Over time this will keep the soil around the earth loop slightly warmer than it would otherwise be without the solar assist. This operating mode is particularly appealing in late winter and early spring when the fluid temperature supplied by horizontal earth loops is bottoming out at the same time solar gains are getting stronger.

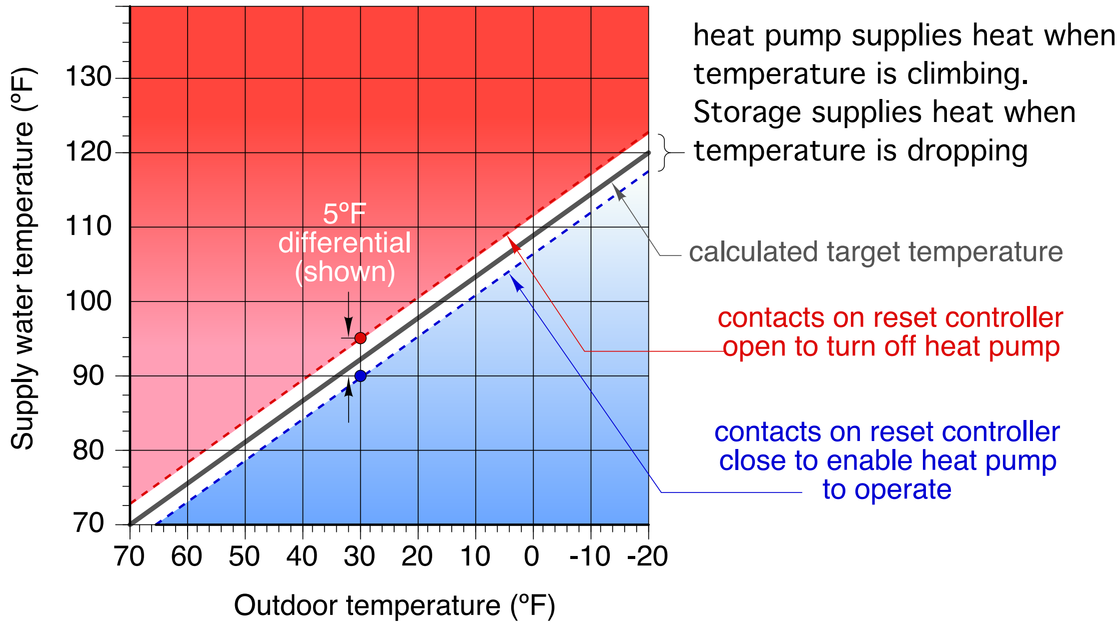
In past columns I've tried to emphasize the point that the lower the operating temperature of the collectors, the higher their thermal efficiency. For example, a typical flat-plate collector operating with an entering fluid temperature of 40° F, at a time when the solar radiation intensity is 250 Btu/hr/ft$^2$, and an outside temperature of 30° F, has a thermal efficiency of about 67%. If the inlet temperature to this collector was raised to 120° F under the same ambient conditions, its thermal efficiency would be only about 37%. This implies that the collector operating at the lower temperature is gathering about 80% more heat than the collector operating at the elevated temperature.

Based on this, some of you may be thinking, "If the efficiency is so much higher, why not just connect the collector array to the earth loop and forget about operating it at a higher temperature for domestic hot water?" The answer is based on two considerations: First, if "auxiliary" water heating is provided by an electric element (or electric tankless

> **Figure 1.**



> **Figure 2.**




heater), the cost of that heat may be three or four times greater than the cost of heat produced by the heat pump (assuming the latter has an average COP of 3 or 4).

Thus, displacing heat produced by the electric heating element will always be more cost-effective and should be the "priority" mode. Secondly, if the collector array is only connected to the earth loop, it serves no purpose during warmer weather when the heat pump is operating in cooling mode. In this mode the earth loop should remain as cool as possible. During this time there's plenty of solar energy available to heat water, but no way to collect it.

When the heat pump is operating in cooling mode, the diverter valve directs the hot antifreeze solution returning from the collector array through the heat exchanger in the solar storage tank. In this mode the solar subsystem is effectively isolated from the heat pump system.

## Other Possibilities

The foremost "Achilles' heel" of closed-loop, antifreeze-based solar thermal systems is what to do with excess solar heat in summer. Simply turning off the collector circulator if the storage tank reaches a high limit can cause rapid degradation of glycol-based antifreeze fluids within the collector. It can also cause steam flash in the collector array and the opening of the collector circuit pressure relief valve.

The system shown in Figure 1 allows the option of dumping excess solar heat gain to the earth loop. The diverter valve directs fluid from the collector array through the brazed-plate heat exchanger in the earth loop while the earth loop circulator operates.

In heating-only systems, or systems with minimal cooling load, this heat dump mode is easy to implement. The possibility of "overheating" the earth loop due to occasional heat dumping is certainly less in Northern climates where earth loop temperatures, even during late summer, are in the range of 65° F to 80° F. However, this mode may or may not be viable in locations with long/hot summers, and thus significant cooling loads. I see it as possible provided the temperature of the earth loop fluid entering the heat pump doesn't rise above a point where heat pump cooling performance is significantly reduced. This could be detected by a setpoint controller with the subsequent action of invoking another means of heat dumping. This also assumes heat dumping is an occasional occurrence, rather than something that occurs every sunny summer day.

## More To Come

It's possible to combine solar subsystems and geothermal heat pumps in other ways. One uses the solar array to add heat to the same storage tank that is otherwise heated by the ground-source heat pump. A coil heat exchanger suspended in the upper portion of this tank, or a brazed-plate heat exchanger outside the tank serves to preheat domestic water. I had such a system in my own home for several years and it worked well. I would likely still have it had we not added building space that required more capacity than the heat pump could deliver.

I expect more research will be undertaken on how to best combine arrays of solar collectors with geothermal heat pumps. The "optimal" configuration must address the relative size and timing of the space heating, space cooling and DHW loads. Look for this combination of subsystems to remain a popular topic in the future. **pme**

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