Design Considerations for Installing a Solar or Radiant Heating System

Solar Consultants, Inc.
P.O. Box 1254
Carrboro, NC 27510
(919) 831-5304
www.solarconsultants.com

This is a planning guide for homeowners and contractors involved in construction in which solar water heating and/or hydronic radiant heating system is to be installed. Much of this applies to all types of solar or radiant heating systems; considerations that apply only to a certain type of system are noted as such. Active solar heating can be added to most any house; much of what I state here are design goals, not strict requirements.

This is not intended as a primer on solar or radiant heating. However, one technical distinction of systems must be noted. Active solar heating using fluid is either of:

a) the **pressurized type**, in which a non-toxic antifreeze solution circulates through the collectors and heat exchanger to pass its heat to the domestic water; or

b) **drainback type**, in which a water/anti-corrosive buffer solution is pumped through the collectors and heat exchanger, then drains back into a small storage tank when the system turns off at night.

There are advantages and disadvantages to each type. Either type is protected from freeze damage; the drainback is better protected from overheating and so can be sized for space heating and commercial installations. For single-family domestic water heating the pressurized type has the advantages of being quieter and using less electricity for the pump -- it can even be powered by a small photovoltaic panel.

A few design considerations differ for the systems –- the main one being that if it needs to drain back, the collector array and piping **must be sloped** all the way back to the tank. The collector array will not be horizontal; it must slope slightly from one side to the other, which is generally not noticeable for a two-collector set, but for a larger array sometimes makes for an aesthetic challenge.

Space Planning:

The most obvious consideration is to provide **unshaded**[1] **South-facing area**, usually on the roof. A system intended mainly to provide domestic water heat can be put on as little as a 5'x 9' roof area, although a two-panel system – requiring about 9'x 9' – would be more typical. To provide **space heating** in addition to domestic water heating, expect to mount **at least four** 4'x 8' panels and allow at least one foot on each side for piping. The collectors will be mounted at a 35-55˚ angle (pitch from horizontal) and so may need to be tilted up (on supporting legs at the tops) if the roof pitch is less than 8 in 12. If the roof does not face generally South the collectors may need to be tilted up so as to face the sun. Or, instead of tilting up, extra collectors can be used to compensate for the less than ideal angles.

Installation and future maintenance of the collectors will be less expensive if the roof is an easy place to work. For particularly steep and tall roofs we sometimes use a crane to lift the collectors. The temperature sensor and insulation on the collector pipes may need maintenance at some time in the future. It is not unheard of to have a storm drop a limb and break the collector glazing. The collectors may have to be temporarily disconnected and moved aside for re-roofing someday, too.

Putting the previous two paragraphs together shows that the ideal roof for a solar installation faces South, has a 12:12 section about 9' tall on which to mount collectors, and has an easy-to-work-from 4:12 or 6:12 section just below it.

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[1] Think in the long term. Given existing trees and your landscape plans, will this roof remain unshaded for the next 15-20 years? Are you willing to trim trees to maintain that?

The pump(s) and storage tank(s) used for solar heating are typically installed in a **utility area**[2] near the backup water heater tank, or in the crawl space or garage. The preferred vessel for a pressurized system is an 80-gallon water heater which has a heat exchanger built into the lower portion and an electric element up top for backup. Having the heat exchanger in the tank means only one pump is needed (to move the antifreeze) and the potable water stays in the tank and does not get stirred up. However, a standard electric water heater may be used for solar storage/backup by adding an external heat exchanger and potable water pump. In that case, water to be heated by solar is drawn from the bottom of the tank and returned near the top. In those systems the backup is either the upper electric element (lower one is disconnected), a second electric or gas water heater, or an external gas burner. It is not practical to use a gas water heater as the solar storage tank, since it is fired from the bottom.

The tanks mentioned above can be used for drainback systems, but the preferred vessel is an unpressurized tank made specifically for solar use. It includes heat exchangers as needed for domestic water, radiant floors, spa, and/or pool heating. These are available in sizes from 50 to 600 gallons "off the shelf" and can be ordered in sizes beyond that.

If the solar and backup heating are to use separate tanks, **allow space for an 80 gallon water storage tank** (approx. 28" dia.) next to the backup water heater. If they are to be done in one tank, **extra capacity is required** to allow the water to stratify. In this case plan on installing a water heater larger than normal. That is, for a family that might typically get by with a 40-60 gallon tank, allow space for an 80; in place of an 80, allow for a 120.

If the backup is to be an external gas heater (or boiler), or an instantaneous (also known as “tankless”) heater, then the backup burner may be remote from the storage tank. Since insulation around pipes is not nearly as effective as that built into a water heater tank, everything works more efficiently if the plumbing runs are kept short, both to the backup heater and to the points of use. A recirculation system -- one that continually circulates hot water around the house to keep it near the faucets -- loses a lot of heat and may keep the storage tank stirred up so it cannot stratify. If your plumbing runs to distant faucets are long and you think you may install a **recirculation pump**, let the solar installer know this in advance so that its return line can be installed so as to least disturb the solar heating.

If this is to be a drainback system using a water heater as storage (as opposed to the special drainback tank described above) allow space near the storage tank for the **drainback tank**. This is normally 12-16” in diameter, 36” tall. Drainback tanks for systems sized for space heating can be as large as is needed; 60" x 40" x 48"h would be typical.

For either type of system **allow a 12” radius clear area** of floor and wall space near the storage tank for access to pumps and piping.

The solar and backup tanks and piping can never be perfectly insulated and so shed considerable heat. In winter it is a bonus to have this heat inside the insulated space of the house; in summer you’d like it out. It is possible to achieve a good compromise by having this equipment isolated from the rest of the house by insulated walls, with large vents high and low in one or more walls that can be opened in winter[3] to let air convect through into the living space, and outside vents that can be opened in summer. This can incorporate well into a “mud room”.

The solar pumps, while fairly quiet, do make a steady **hum** during the day. **Drainback systems are louder** than pressurized (anti-freeze) ones. Avoid building a common wall between the utility room and an office, study, or living room space; or if there must be a common wall, build it with good sound insulating methods. Closets, bathrooms, and bedrooms that are not used during the day are better neighbors for the solar pumps. The same consideration applies to pipe runs to and from the collectors. It is useful, though, that there be some place where the occupants do hear the system running. That flow reminds them every time of the money they are saving, and –- if the sound changes from what they have learned to expect -– is a good troubleshooting alert.

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[2] This utility area is not necessarily the same as a utility room where the clothes washer and dryer are, although most of the planning considerations for noise, heat, and leak containment are the same.

[3] This also helps prevent pipe freezing in exceptionally cold weather.

Radiant floor pumps make similar noise during the heating season. This may be a problem if the radiant heating pumps are hung on a common wall with living rooms or bedrooms. Said hum, by comparison though, is steadier and much less loud than a refrigerator, a gas furnace firing up, a heat pump or air conditioning compressor, or air motion through ductwork. Power-vented gas backup heaters, which include all high-efficiency models, have fans that can also be a bit noisy.

The standard radiant heating pump and control **module requires a minimum 24" square** of wall space for each separately controlled group of piping loops. Most houses need one module; those with radiant loops in areas of quite different heating need, such as concrete on the basement floor and wood as the second story floor, may use two radiant heating modules.

The **source of heat for our radiant modules** is a gas-fired water heater (of any type), so this must be sized to support the heat load of the house in addition to domestic hot water needs. If this heat source turns out to be undersized, a flow switch or thermostat can be installed to temporarily disable floor heating while domestic hot water is being drawn, to afford it priority.

Plumbing:

If you are on a well -- even if it is a community well -- **have your water tested** for hardness, pH, and iron content. These are the most common problems in this area and can affect the choices of and longevity of your plumbing. For instance, if the water is extremely hard or iron-laden, an instantaneous water heater's heat exchanger or an electric water heater element may foul prematurely. The best plan is to treat the water to bring it within normal bounds before installing any other plumbing. It is best to know as soon as possible if you need to allow space, electricity, and access for water treatment tanks.

Ideally the **floor of the room with the water heaters** would be lower than the main floor and be provided with a drain. If such is not the case, drain pans should be installed underneath all water tanks, unless they are in the crawl space. We do not encourage the installation of water tanks on levels above the lowest floor, because with any pressurized water system there is the potential for leaks that refuse to run conveniently into the drain pan.

For a drainback system there must be **continuous slope** in the solar pipe runs from the lower end of the collector panels on the roof to the heat exchanger and solar fluid tank. This can almost always be accomplished, but must be planned before other plumbing, ductwork, etc. occupies the needed route.

If the **attic** may someday be finished, pipe runs to the collectors should be routed outside what will become the walls.

Aside from the pipes to the collector area the plumbing for solar heated water is the same as any other. Because solar heated water has the potential to be hotter than that coming from an electric or gas heater, we recommend the installation of a **tempering valve** – which limits outlet water temperature – at the water heater, unless the solar is always a pre-heater to a large backup heater tank which will itself temper the water.

Radiant heating pipes are most often installed in a poured slab or concrete wall, in which case the pipe is stapled below or tied above the reinforcing wire mesh shortly before the concrete is poured. Installation on a subfloor (to accommodate wood, carpet, or tile final flooring) can be from above (with "sleeper" boards between pipe runs) or be stapled up from below. If done from below, the crew doing the final flooring and door thresholds must be warned about the pipes below. No nails or screws should stick through the subfloor.

Sub-floor **insulation** becomes even more important than usual when the floor is the heating element. For slabs, 1" extruded polystyrene underneath is minimal; 2" is preferred. Perimeter insulation is the most important, with 2" being the minimum vertically and horizontally within 24" of the perimeter.

If the hot water pipes are within the insulated building space, the radiant heating module warm water intake can be connected from the most distant faucet instead of directly from the water heater. This turns all the hot water piping into an extension of the heating system plus provides instant hot water at the faucets during the heating season without the expense of an extra recirculating pump.

If you are radiant heating a bathroom floor, order a **non-wax PVC sealing ring** for the toilet. Overheating the floor could melt a wax ring.

And finally, with a solar or radiant installation there often will be **two plumbers or two mechanical (heating) contractors** involved in your job. Introduce them and make a clear demarcation of who is expected to supply which equipment or piping and how it is to interconnect.

Wiring:

Have the electrician install a **120V duplex outlet** near (but not behind) where the water heater(s) will be for the solar control (unless the pump is to be powered by its own PV panel) and one for the radiant heat module. The current draw is very slight -- about one to two amps for each of these. It is best that these not be isolated, that is, that they be on the same circuit with other lights or outlets. That way you'll know soon if the breaker trips. Codes may require this to be a ground fault interrupt protected outlet, especially if it is installed in a crawl space. A switch can be set in a convenient location for the radiant floor system if the pump and control module is in the crawl space or otherwise inconvenient. The radiant heat thermostat is normally mounted on the pump module, but a **remote thermostat** may be located in a more convenient spot. Some of the solar water heaters with a backup electric element installed use a larger-than-standard 6000 Watt element, and your electrician should be aware of that.

The copper solar fluid pipes may have to be grounded (check with the electrician if being threaded into the tank and/or grounded pump is sufficient.) In this case, have the electrician install the ground wire to be clamped to the pipes.

The solar system installer will usually install all the necessary low voltage control wiring (sensor, remote thermostat or display). If you wish only to rough-in the installation now for completion in the future, the **minimal** wire to install for solar is one pair 18ga thermostat **wire from the vicinity of the water heater to the attic**, with enough spare to reach the top of the collectors. If other sensors are to be installed for display or data logging add wires accordingly. Shielded, UV-resistant cable is preferred. If the water heating system is to be powered by a photovoltaic panel run 16 ga. or heavier wire from the attic to pump(s). The thermostat and sensor wires for radiant heating vary with the design.

If you are installing an **external gas backup heater,** it may (depending on model) require an outdoor line with an outdoor rated switch just below where the unit is to be mounted. It also, of course, requires either natural or LP gas. Requirements for indoor-mounted instantaneous heaters will vary. A **tank-type gas water heater with a power vent** also requires an outlet.

If you are using radiant floor heating consider using electrical radiant heat ceiling panels to complement in areas needing extra warmth. This would allow you to keep the overall floor temperature lower, but have extra warmth in the bath, at the dining table, or over the living room couch, for instance. They can be wired through motion detectors, so they turn on only if a person is in the room. For small areas such as bathrooms, space heaters with very quiet fans that heat using hot water are available, as are heated towel racks. For a truly cozy bath, install a separate, slightly higher temperature radiant zone in the floor and walls of the bath(s), especially shower walls and those surrounding the toilet.

Collector Mounting:

Usually collectors are mounted on top the finished roof, although some designs allow flashing the collectors into the roof as you would a skylight. When mounted atop the roof the collectors stand off the surface on feet that are lagged or bolted down. There are usually four sealed penetrations per collector, plus two for the pipes and wire. Large arrays often use an aluminum frame to support the collectors with fewer penetrations.

Timetable:

We need to do parts of our work at certain times in the building process.

Do This Stage:	After:	but Before:
Size room spaces for solar and radiant, plan layout and routing of pipes and wire; coordinate with other plumbing and electrical	You have sketch of floor plan	Construction plans are finalized
Test water quality (if on well); plan for correction of hard or acidic water	Well is drilled	Decisions are made on plumbing layout and choice of water heating components
Lay and pressure test radiant pipes (if on wooden floor)	Depends on construction method; usually after subfloor is down	Floor finishing above or ceiling finish below level of pipes; also before floor is insulated
Lay and pressure test radiant pipes (if in concrete)	Foundation wall or form, drain rough-ins, gravel, termite treatment, vapor barrier and under-slab insulation are in place	Reinforcing wire mesh is laid. Loops must be pressurized for slab prep inspection before pour.
Rough-in solar pipes and sensor or PV wires	Framing, roof, dried-in. Sometimes pipe flashings are installed before finish roof.	Other rough-ins that may interfere with getting to needed pipe run (specifically HVAC ducts). Insulation or drywall is installed
Install collectors	Roofing is complete	Extensive landscaping if that would compromise access
Install water storage & backup heater	Wall finish in utility room	Plumbing final inspection
Install radiant heat module and plumb to floor loops and source	Wall finish in utility room	Plumbing or mechanical final inspection
Begin using backup heating	Water and electricity are stable, all air has been purged from tank(s) and pipes	
Install solar pumps, begin using solar	Can be done with other plumbing trim	
Homeowner takes advantage of tax credits	Solar (either passive or active) is operating	Two years for federal and five years for NC. See www.solarconsultants.com for tax credit information.

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