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Considerations in Choosing a Backup Water Heating System

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This is an outline of options for a backup, or auxiliary, water heating system, that is, the one that comes after the solar heating, but applies equally to a stand-alone heater with no solar input. Since I am attempting to describe systems with and without solar and with and without radiant heating in addition to the usual domestic hot water load, there will be parts of this document that do not apply to your situation. Any prices mentioned in this document are as of 6/2009 and are for purposes of system comparison rather than to be considered a quote.

The variations discussed are: solar/electric in one tank, electric or gas non-solar tank-types, instantaneous (tankless) electric or gas, and the Phoenix hybrid solar/gas tank heater. The basic considerations apply as well to boiler-heated indirect tanks. Not included in this document are electric heat-pump water heaters, since these are not yet common and, unless the refrigerant-to-air heat exchanger is outside, during the heating season these simply turn a water heating issue into a space heating problem.

Variables to Consider

For domestic water heating, there are several things to consider:
1) the maximum flow of hot water you need at any one time (e.g., how many users will be drawing hot water at once and what is the flow to each),
2) how critical the temperature is to those uses (in a shower, for example, strict temperature regulation is much more important than for a clothes washer or a radiant floor),
3) the volume of hot water that would be expected to be drawn in a short time --before the system has a chance to recover --, and

4) up-front cost, tax credits (currently for solar and high-efficiency gas heaters), operating costs (including pollution generated), lifespan, repair costs, and how these different types are effected by bad water quality.

In a system built around a solar water heater, the least expensive backup option is to wire the 4,500 or 6,000W upper element of the solar storage tank. This maintains the top third of the tank at thermostat temperature and is usually sufficient for one or two persons' use, if no radiant heating is installed.

Alternatively, a separate water heater, either electric or gas-fired, can be added in series after the solar tank instead of, or in addition to, wiring the solar tank's element. Electric is less expensive to install (no gas line of vent flue needed), but has a higher fuel cost than natural gas at current prices. Gas water heaters have a shorter recovery time (time required to reheat the tank as cold water enters.) The disadvantages of a standard gas water heater are burner inefficiency — a typical gas tank-type heater is in the realm of 55-65% efficient — and that it has a relatively poor ability to store heat due to standing loss because of the flue up the middle of the tank. Models that are more expensive can overcome this partially with flue dampers and fan-assisted venting.

A forty- to sixty-six-gallon water heater would be sufficient for most households without radiant heating, or compact ones with radiant heat.

A house with a combined hot water load of domestic and space heating (with a radiant floor, hydronic kickspace heater, or Hydroheat (water-to-air heat exchanger in the air handler)) generally places such a large demand on the water heating system that it calls for a fuel-fired, instead of electric, backup.

With any tank-type water heater the rate of flow is not a problem. That is, there is very little restriction of flow through the tank, so as long as your overall water pressure is good and the house plumbing is sized properly, several short uses of hot water at once does not cause pressure or temperature fluctuations. Longer-term temperature regulation can be a bit sloppy because tank thermostats are not very precise, but are usually adequate. (This imprecision is not true of the Phoenix, mentioned below.)

In specifying a tank-type heater, the household's needed hot water volume in a short-term (i.e., the number of simultaneous uses and how much water each needs) defines the lower size limit, and repetition of draws defines the necessary speed of recovery. Volume comes into play in filling a large tub or in having several draws in quick succession that might use up all the hot water in a tank before it can recover.

By comparison, an instantaneous (tankless) heater has no volume limit — it can supply hot water for as long as the fuel holds out — but can only keep pace with a certain amount of flow (usually 4 to 8 gallons per minute — more if it has solar pre-heating) due to both the convoluted path through the internal heat exchanger and the limit of its ability to burn intensely enough to heat the water as it passes through. Exceed that rated flow and nothing terrible happens, but the temperature will fall off, so both flow rate and temperature regulation are limiting factors for an instantaneous

heater, especially when the radiant floor is a user that could make an unannounced demand for hot water.

There are several ways to satisfy these needs and, as with most things, the higher levels of efficiency (lower operating costs) come with a higher up-front cost. Use of radiant heat puts higher demand on the water heater, but, in the case of a tank-type heater, this is really a good thing in that continual use of hot water cuts the percentage of standing loss (the loss through the insulation of just keeping a tank hot) and means that any money spent on efficiency is paid back even faster. The web site http://www.aceee.org/consumerguide/waterheating.htm discusses how to make comparisons, but does not name brands.

standard tank-type gas water heater

The cheapest and least efficient way to provide enough heating power for domestic hot water plus radiant heat is a standard tank-type gas water heater. These start at about 53% efficiency – that's how many Btu's of water heating you get for burning 100 Btu's of fuel– and go up to about 65%. Direct vent units are no better in efficiency, but some power-vented ones get into the 70% range. Both of these draw combustion air from outside, which is an advantage if it is to be installed inside the conditioned space. Standard sizes are 30 to 72 gallon, with Btu/hr. inputs of 30,000 to 70,000. For combined domestic and radiant heat loads, we would be looking at the upper end of the burner sizes, 50,000 – 70,000 Btu/hr, which are, unfortunately, the least efficient. They usually have six-year warranties and need to be replaced in about 12 years.

Instantaneous Water Heater

The next option up the price scale is an instantaneous water heater. A Rinnai R75LS, to cite a popular model as an example, has an efficiency rating of 82% and costs (with through-wall vent kit and valve set) $1820, plus sales tax, plus ~$450 labor. Newer, more efficient **condensing burner design** heaters, such as the Bosch Aquastar GWH C800 or Noritz 841, are more expensive up front ($2,350 – 2,500 parts, $800 labor for installation), but save money in the long run on gas costs. (None of these prices include rough-in of water or drain pipes, gas pipe or regulator, wiring the 120V electric outlet, or flue venting beyond three feet, and all are subject to change and adjustment for unusual installation requirements.) These can provide plenty of heating power (up to 185,000 Btu/hr.) and a longer life than a tank if it is kept de-limed (see "water quality", below.) The only snag is that the Bosch GWH C800 is not officially rated for or warranted for space heating. Many are doing that very job in moderate climates such as ours with excellent records and performance, but other models and brands are warranted for radiant. Paloma and other brands offer models with ratings similar to the R75, but probably not at the same quality. (See the ACEEE web site, above, for a list of manufacturers.) Warranties range from 5 to 15 years. The Rinnai LS models, for example, are rated for radiant heating, but at a reduced (from 12-year to 5) warranty on the heat exchanger.

If it seems that the simultaneous hot water uses might exceed the capacity of the instantaneous (models vary greatly, but typical is about 6.5 gallons per minute) it can be

coupled to a **buffer tank**. This adds almost $2000 plus tax and $1,000 labor to the above and means you have the advantages of the efficient, fast-recovering burner with the freedom from flow restrictions you get from a tank. This is particularly an advantage if there is solar input to the water heating, or if the hot water is also used for radiant floors. (The cost of adding this will be less if there is a solar tank that can act as the buffer. Please see the document "Instantaneous as External Burner" for details.) But if this option appeals to you, be sure to read on to the next section.

Phoenix High-Efficiency Tank-Type Gas Heater with or without solar heat exchanger

The next step up in efficiency and price is a Heat Transfer Products **"Phoenix" condensing burner, stainless steel tank-type** water heater. These are top of the line and have all the advantages of the above plus a very, very long life for the tank, 97% efficiency, and plenty of heating power (100,000 Btu/hr. or more) at an installed price of $4,430 plus tax ($5,900 for the solar heat exchanger models). This combines all of the advantage of the tank type — without the rusting-out — with greater efficiency advantages than the instantaneous — without the pressure drop issues — with a super-fast recovery rate. And the **hybrid gas/solar** "S" models also do the job of the $1300-$1700 solar storage tank. (So, in figuring total cost, subtract this amount from the solar system cost.) These are available in 55-, 80- and 119-gallon models. Installation is more involved than with an instantaneous, but since the Phoenix is power-vented through 3" PVC pipe, this is somewhat easier than venting a standard gas water heater.

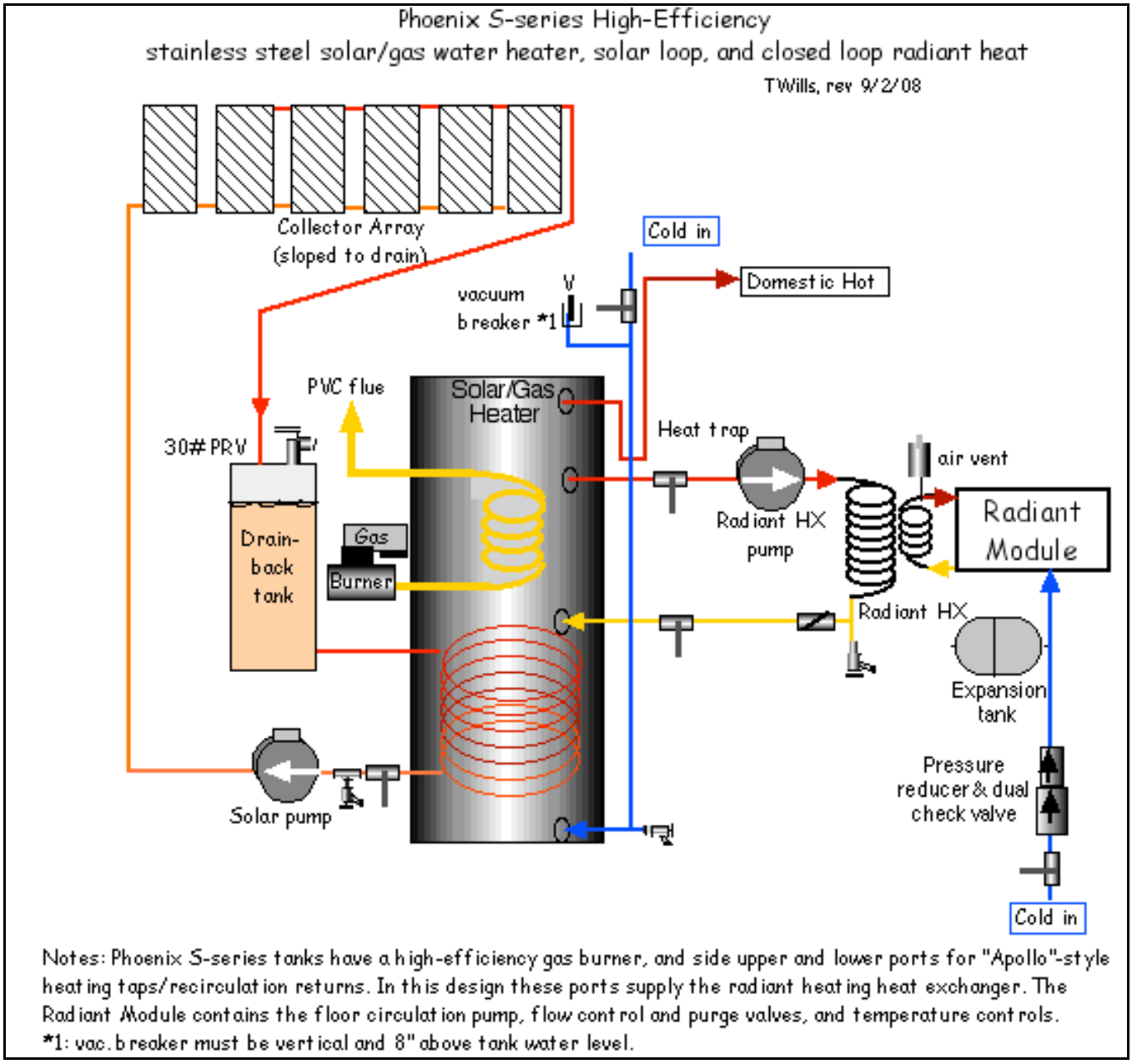

Figure 1. Phoenix with solar and gas inputs, supplying domestic hot water and radiant floor heating.

Solar Water Heating

Solar water heating trumps anything mentioned so far for energy efficiency. A system sized to provide a yearly average of 80% of domestic water heating for a family of three with a PV-powered pump operates with no outside source of power; a plug-in system uses about $1.50/month of grid electricity. Such a system costs ~$7,100 - $7,700 plus $320 tax, installed. (2009 pricing for an AC-powered, two-collector, pressurized glycol system with an 80-gallon storage tank and no upgrades such as drainback.) Solar water heating can be used in conjunction with almost any type of backup heater, and the solar-heated water storage tank

can also function as the buffer tank mentioned with the Rinnai, above. The "S" model of the Phoenix gas water heater has a solar heat exchanger built-in.

For families or businesses with need for more hot water, or to contribute more to space heating, we can size the solar heating up (make it a drainback and add more collectors) at a cost of ~$700 for the drainback tank and upsized piping, and $1,200 per 4x8 collector. Each collector adds about 20,000 Btu per sunny winter day, 30,000 in summer. The only upper limit to this array is the number of collectors that could fit on the south-facing roof area and the amount of heat you can put to use.

Tax credits reduce the first-year cost of solar systems by 35% (NC, with a cap of $1,400 for domestic water heating only, or $3,500 for combined water and space heating) plus 30% (federal) for domestic water heating. An example system with an installed price of $7,500 has a net cost of $3,850.

There is also a federal credit ($1,500 max.) of 30% of cost for the purchase of a high-efficiency (≥.82 rating) gas water heater.

Maintenance and Longevity

One other factor to consider is **water quality**. It is much more critical to an instantaneous water heater that the water not be too "hard", as the following excerpt from a Bradford-White test setup shows:

"Testing showed that lime scale build-up is a major concern in hard water areas with tankless water heaters. Lime scale did not flush out of the heat exchanger from the water velocity through the coil, but accumulated in a very short period of time. Lime scale can also accumulate on the base of storage water heaters, but much more gradually, making storage water heaters more tolerant of hard water conditions. Adding a water softener on the water supply would prevent the quick accumulation of scale on the heat exchanger. Tankless #2 [a Rinnai or similar] started out with a higher efficiency rating, but dropped off for the two-week period of operation due to scale buildup in the heat exchanger. The efficiency rating could be up to two points higher using softened water. Tankless #1 [an Aquastar 125 or similar] was less sensitive to scale build-up, but still lost about 1.75% operating efficiency after a two-week period of hard water conditions. Both tankless water heaters have a procedure to remove the lime scale from the heat exchanger by flushing with vinegar using a circulator. This requires at least one hour of service time, adding to the life-cycle cost of the tankless water heaters in hard water areas. To maintain peak efficiency, the tankless models must have water conditions with less than 11 grains of hardness. The MI40T and M440T [tank-type] models did not show a noticeable drop in efficiency during the test program. "

The Phoenix installation manual gives water quality advice as: hardness should be a maximum of 25 grains per gallon, pH between 7.2 - 7.8 (outside the 6-8 range failures are not warrantable) and total dissolved solids less than 2,000 ppm. (above this will coat the heat exchanger). Bosch/Aquastar says: total hardness maximum of mg/l or ppm 100 (6 grains); pH from 6.5 - 8.5; TDS (total dissolved solids) less than 500 mg/l or ppm.

The life of a steel (or "glass-lined") water heater is usually 10 to 20 years. This is

dependent on water quality (acidity shortens it considerably) and can be pushed toward the longer end of the bell curve by replacing the anode rod every 5 years or as needed. The tank itself is not repairable. If an instantaneous heater's heat exchanger or other water passage part gets clogged beyond de-scaling, it can be replaced. The Phoenix burner/fan assembly is repairable and the tank should last a lifetime. The Phoenix warranty for residential installations is 1 year parts, 7 years tank. Other tank-type water heaters often have six-year warranties, with a few of the more expensive ones being twelve years or lifetime. Instantaneous water heater warranties are usually ten to twelve years.

The standard disclaimer of "your mileage will vary" applies here as well. In terms of reliability and reparability: a solar water heater is a mechanically very simple device; an electric tank-type heater is electrically a very simple device; anything else is more complicated. But despite the bewildering wiring and sensors of a modern instantaneous water heater, good brands have so far proven very trustworthy.