Renewable Heating System Options in New Construction

Choosing the right renewable energy system for your project is a personal and highly specific task. We believe our job is to recommend high quality technologies that are proven to be reliable and environmentally friendly, and then collaborate with you to determine what will best suit your specific project goals. There are two aspects to any heating system; source and distribution. The source is what creates the heat and the distribution is how that heat is dispersed through the building. Understanding the heating requirements unique to your project is the first step in figuring out how to meet them.

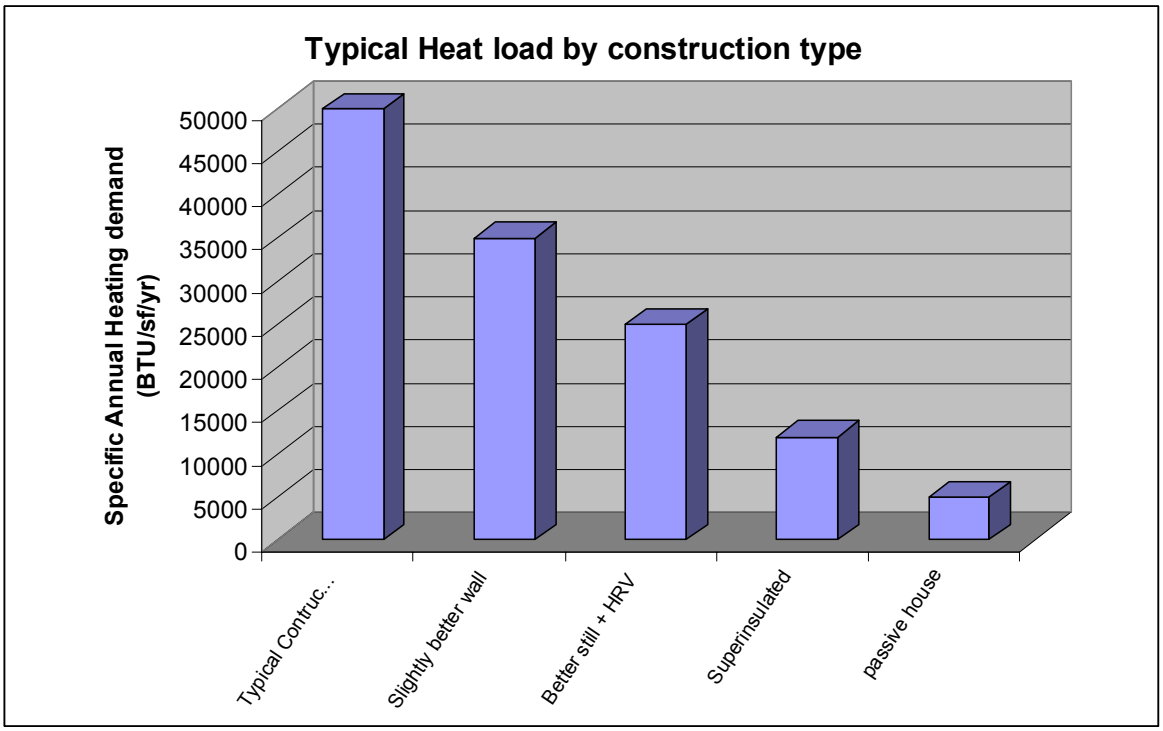
Home Envelope Performance:
The first question to answer is just how much heat do we need to keep the house nice and comfortable. Obviously this heat load varies both with the size of the building and the performance of the building envelope. One metric we find useful to compare the heating performance of various buildings of different sizes is the specific annual heat energy demand. We calculate it in units of: BTU/sf per year.

A typical Maine home built conventionally to the present building standards (5.5" of fiberglass insulation, double-pane windows and decent, but not exceptional, workmanship) will require about **50kBTU/sf per year**. In other words, each square foot of conditioned space requires 50,000 BTUs in a typical heating season to keep it warm. As an example, a typical 2,000 sf home built to this standard would require about 800 gallons of heating oil in the heating season. The house would probably use another 200-250 or so gallons of oil in the non-heating season for domestic hot water.

With some attention to detail in air-sealing, window selection and placement, a somewhat better wall (like cellulose in the cavity and a 1-2 inch rigid layer to stop thermal breaks), we've found it is relatively easy, when building new, to get into the range of **25-35,000 BTU/sf/yr**. Imagine that; for just a little effort in the wall system, you can essentially halve your heating load (and bill).

As building insulation improves, more and more of the heat load for a house comes in the form of energy required to heat fresh air, which is needed to keep the house healthy and comfortable. To keep healthy air while continuing to reduce infiltration and achieve specific heating loads of **less than 25,000BTU/sf/yr** tends to require an HRV or ERV, which is a mechanical ventilation system that recycles the heat that would otherwise leave the house as fresh air comes in (http://en.wikipedia.org/wiki/Heat_recovery_ventilation).

Finally, as you continue to drive the building performance up, you eventually reach a point where the heating load is so small that it hardly even justifies a boiler or furnace anymore. We've had the pleasure of working on several of these super high performance homes throughout Maine whose heat load is in the range of **12-15kBTU/sf/yr**. And we are currently working on a handful more that are trying to reach the German Passivhaus standard, which is a very challenging **5kBTU/sf/year** http://en.wikipedia.org/wiki/Passive_house



Determining the Annual Load
Now that you know the specific annual heat load for the house you are building, we can get an idea of total annual load by multiplying the square footage by that specific annual heat load.

If you've got a 1,500 sf home that you wish to go all out with insulating, including a Heat Recovery Ventilator, so you achieve a specific annual heat load of 25,000 BTU/sf/yr, your **total annual heat load will be in the 35 to 40 Million BTU** range.

If you do just a decent job insulating, without mechanical ventilation on a larger, 3,000 sf house and achieve 45,000 BTU/sf/year, you'll need more like **130 Million BTUs each year**.

Choosing a heating system option:
If you made it this far in the document, we take it as a given that you are interested in installing a heating system fueled partially (or mostly) by a renewable energy source. There are a number of ways to tackle this problem and which one is right for you depends not only on the size of the total load, but also on your personal preference and lifestyle.
While it would be impossible to describe every possible renewable heating system in detail in this document, below are descriptions of four different systems which all achieve the goal of a renewable energy heating system for Maine's climate.

Professional design, installation and service of renewable energy systems

Solar Space Heating & Domestic Hot Water System Options

System option 1: **Solar Space Heating with High Efficiency Gas Backup**
If your goal is to get a substantial fraction of the home's active space heating requirements from the sun, then we recommend a medium to large-sized evacuated tube solar hot water collector array (180 to 360 Apricus tubes), one or two super-insulated solar storage tanks (160 to 320 Gallons) and backup heat supplied by a high efficiency, wall hung, modulating and condensing propane boiler such as the Triangle Tube Prestige.

The solar hot water system is designed to supply both domestic water heating and supplemental space heating. The Prestige, with just seven parts, provides reliable backup and is easily serviced. The collectors will be mounted on stainless steel lift kits and elevated to approximately 60 degrees to optimize wintertime performance. With an acceptable orientation range from 155 to 245 degrees on the compass, the collectors will be installed facing southward, either on the roof or ground of the home. The solar storage tanks are ideally located in the boiler room, near the boiler and other mechanicals.

On a good sunny day, the solar system will produce a 60-70 degree temperature rise in the storage tank(s) and will be sufficient to provide virtually all of your domestic hot water needs throughout the year. In addition, during the shoulder seasons (early fall and late spring), the system will have excess heat capacity and this capacity will be used to heat low temperature distribution (typically a radiant slab). During the coldest months of the year, when less solar energy is available, the boiler will automatically come on as necessary to supply supplemental space heat and domestic hot water. The solar thermal system will typically supply somewhere between 20-40% of the space heating load, and 95% of the domestic hot water load on an annual basis. A well designed, 180 tube solar hot water and space heating system will produce more than 29 Million BTUs of clean renewable heat energy and, by reducing the amount of fossil fuel that your household will burn to heat water, it is estimated to eliminate more than 6,000 lbs. of CO_2 emissions each year.

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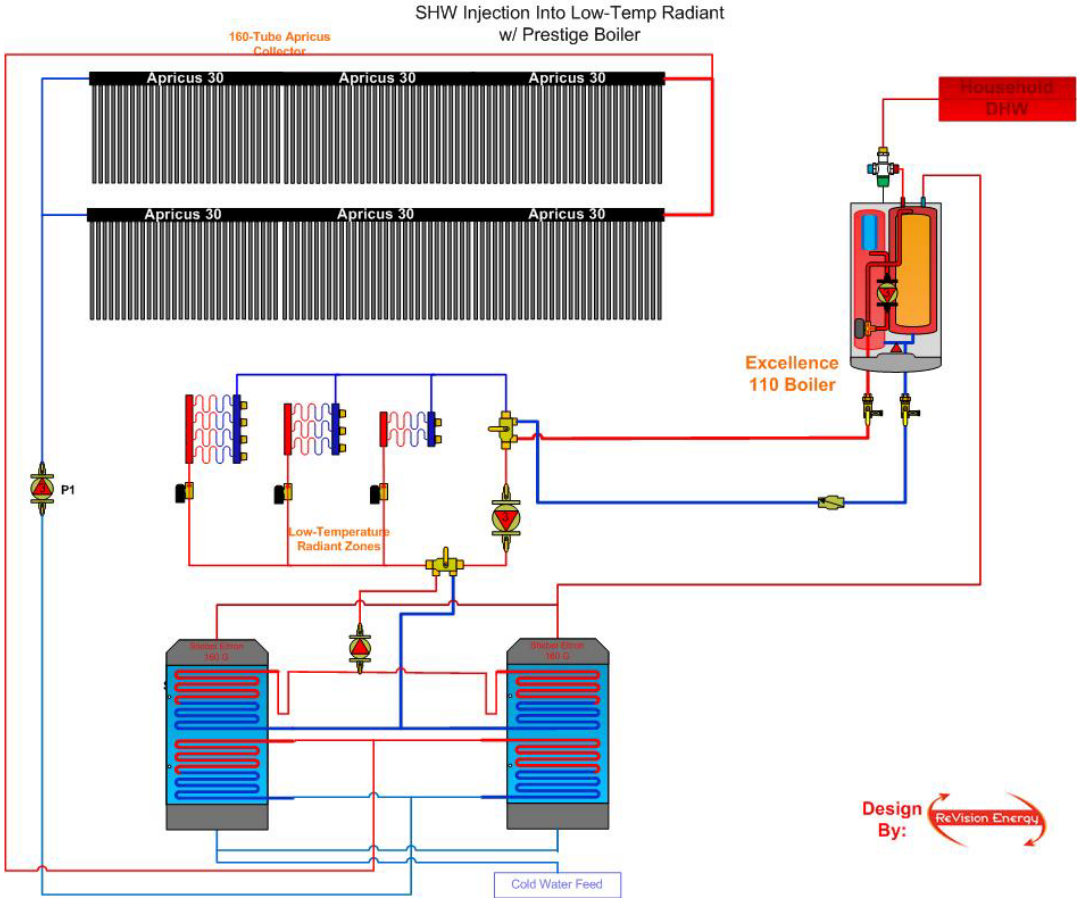
When the sun can't get the domestic hot water or space heating job done, it is backed up by a Triangle Tube Prestige Excellence boiler.
(http://www.triangletube.com/PDF/Prestige%20Cond_Boiler/Excellence_Lit.pdf)
This heating system will be engineered and installed to provide optimum response and efficiency. The Triangle Tube Excellence 110 heating appliance is one of the most sophisticated, well-constructed boilers currently manufactured. Triangle Tube boilers, although rated at 93% AFUE efficiency, are capable of better than 95% combustion efficiency in low-temperature applications, and can modulate down to 25% of the rated input. An outdoor reset control supplied with the boiler matches its supply water temperature to the seasonally-variable heat loss of the building. All of this means that Triangle Tube boilers are among the very lowest in fossil fuel consumption among all other boilers on the market.

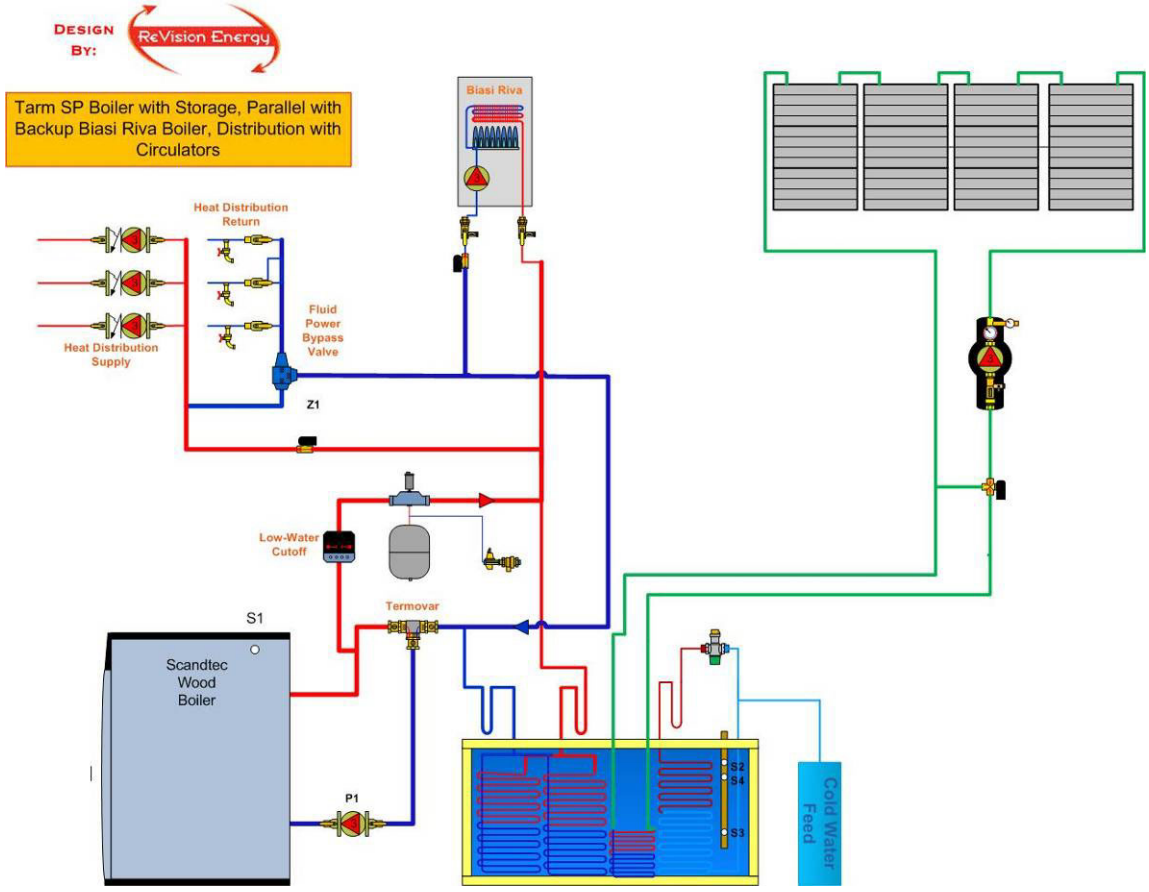
A schematic representation of the boiler and its integration in the heating system is included below:



The solar portion of this system costs roughly $16,000 for 180 tubes to $28,000 for 360 tubes, from which you can subtract the 30% federal tax credit and possibly an additional $1,000 state rebate (though funding for the state rebate is limited).
The boiler and heating system installation will cost roughly $9-12k, which includes everything you see in the schematic above except the heat distribution. (the boiler may qualify for an additional $1500 tax credit as well as additional rebates from your utility or gas supplier).

System option 2: Wood boiler with Storage and Solar Hot Water (Flat Plates)

In our climate, it is challenging to rid yourself of an active heating system altogether. If you really want to eliminate fossil fuels from your home, and shrink your carbon footprint, we believe one solution is to efficiently burn sustainably harvested cord wood or wood pellets. Wood and wood pellets are a local resource and provide a virtually carbon neutral fuel because remaining trees in a stand will absorb the CO2 emitted by the burned trees. We like to think of wood (and pellets) as nature's solar energy storage. The tree absorbs energy from the sun throughout its life, and that energy is then released into your home when the tree is burned.



The best way to burn wood is in a gasifying wood boiler with thermal storage. Unlike traditional outdoor wood boilers, which are polluting and facing strict controls, the gasifying wood boiler combusts every molecule of the wood, enabling it to achieve very high efficiency and nearly smokeless operation. The boiler not only burns the wood, but also combusts the resulting woodsmoke in a secondary chamber at temperatures up to 2,000 degrees F. Adding a large thermal storage tank to the system greatly reduces the work involved in using wood fuel because it lets you build one hot fire a day (or every other day in the spring and fall) to heat the 600 gallon tank and then gradually use the energy stored in the tank to heat the house throughout the whole day. This system allows you to burn wood into the shoulder seasons when a wood boiler without storage becomes impractical to run because of its tendency to overheat the house.

When paired with a thermal storage tank, the wood boiler we recommend is the Tarm Solo Innova (http://www.woodboilers.com/product-detail.aspx?id=45). The final benefit of this option is that since you really can go nearly 100% to wood, and the fossil boiler becomes a backup which is rarely used (maybe only when you are on vacation or just don't feel like loading the boiler), it might make sense to use a slightly less efficient (but also less expensive) boiler than the one proposed in option 1 above. In these cases, we often recommend and install the Biasi Riva boiler (http://www.qhtinc.com/riva.html).

Installed cost for the Tarm Solo Innova with thermal storage tends to start around $18,000. This includes integration with the heating system and propane boiler (though not the propane boiler installation itself) for a fully automatic system. Installation of the Biasi Riva adds about $5k to that.

In many cases, when we install wood boilers with storage, we'll also install a solar hot water system. In this case, the goal of the solar hot water system is to keep the storage tank hot in the summer so that you don't have to burn wood for domestic hot water only, and so that the oil boiler never comes on. These systems are fairly large (for DHW systems) as far as collector area goes (typically four 4x8 collectors), but pretty reasonable in cost because you don't need to buy an extra tank. In this case, we recommend flat plate collectors because typically you are relying on the solar in the warmer months of the year, when the flat plate performance is very good. Rough cost for the solar system is roughly $10-11k (less the 30% federal tax credit).

At left is a photo of four flat plate solar hot water collectors which are ground-mounted on a rack adjacent to an existing home.

This home in Ogunquit is heated by a Tarm wood boiler with storage and the solar thermal system assists with the space heating load in the spring and fall, and carries the entire DHW load throughout the non-heating season

To the right, is a photo of four flat plate solar hot water collectors which are roof-mounted, along with a 2 kilowatt solar electric array.
This home in Brunswick is heated by a Tarm wood boiler with storage and the solar thermal system assists with the space heating load in the spring and fall, and carries the entire DHW load throughout the non-heating season

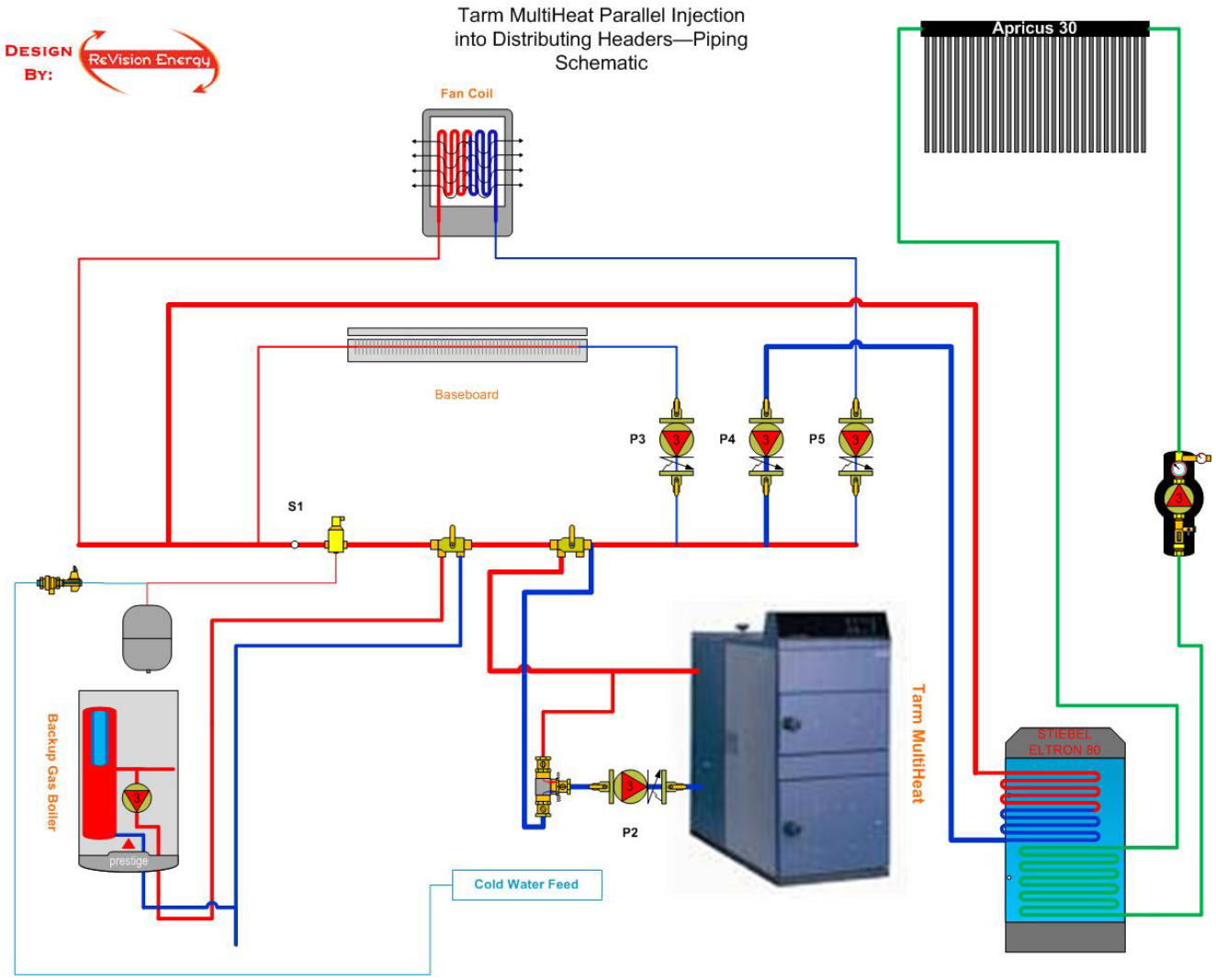
Each cord of firewood produces roughly 20 Million BTUs when burned dry in a Solo Innova wood boiler with thermal Storage. A 2,000 SF house built to decent standards, without a Heat Recovery Ventilator might only require 3 cords of wood for the entire year.

System option 3: Pellet Boiler with Solar Hot Water System

Pellet boilers fall somewhere between a gas boiler and a wood boiler both in terms of cost of the fuel, and also in terms of the interaction required from the homeowner. Typically pellet boilers have been supplemental boilers which are backed up by another heat source (much like the wood boiler above). The boilers are fed from a pellet hopper which the homeowner has to keep full. This requires that every two to three days, the homeowner fill the hopper with 40 lb. bags of pellets and possibly to clean out some ash.

The pellet boiler we install most often is the impressive Tarm MultiHeat
http://www.woodboilers.com/product-detail.aspx?id=54
The MultiHeat is a highly efficient boiler with an exceptional reputation and a strong company standing behind them. A full install of a MultiHeat costs roughly $16 to 20k, plus the cost of the backup boiler.

The 2,000 sf house built to high, but not the very best standards (30,000 BTU/sf/year) would require about 4 tons of pellets per heating season.



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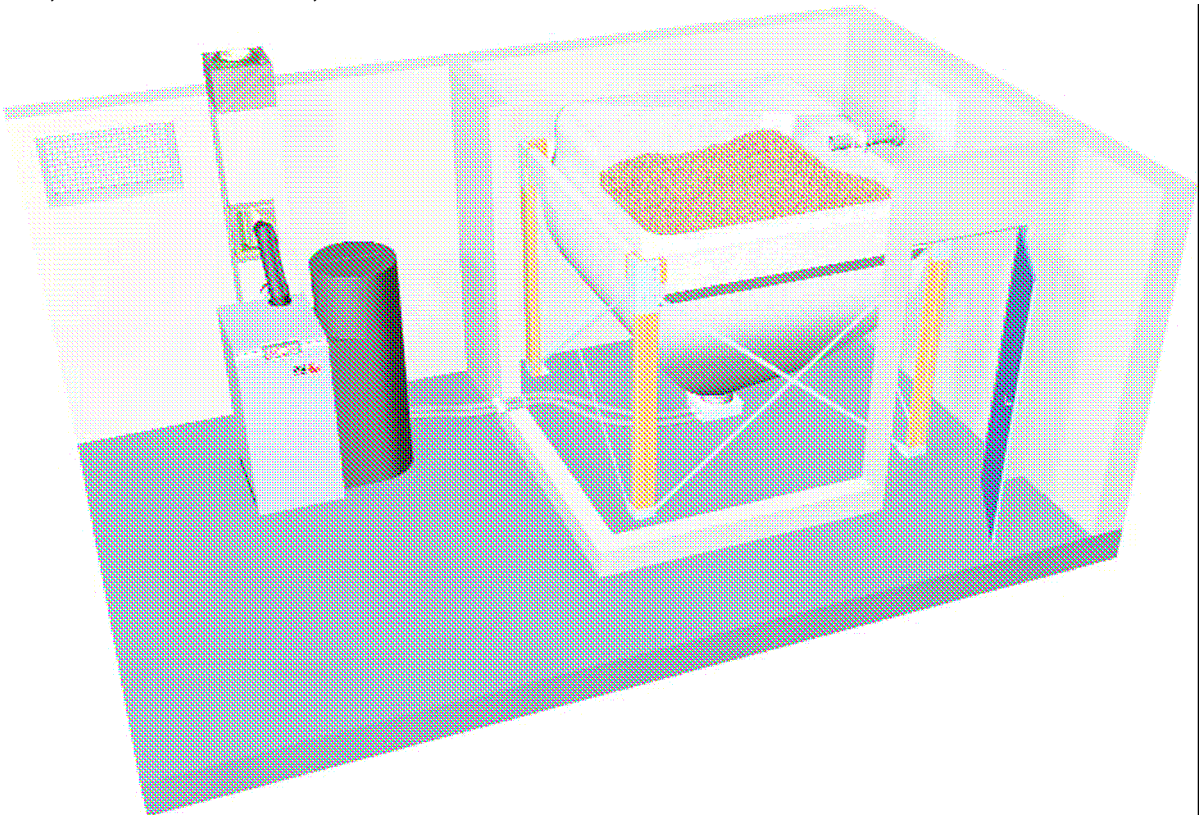
System option 3a: Automatic Pellet Boilers

Another exciting pellet boiler option, which is new to the U.S. but has been available for years in Europe, is a fully automatic, cold start, self-cleaning pellet boiler, like the Frohling P4 (http://www.woodboilers.com/product-detail.aspx?id=40).

These boilers essentially operate like an oil or gas boiler in that they require very little homeowner interaction at all. Cleaning is annual and they draw their own fuel supply from a bulk storage bin, which can be filled by a delivery truck, just like an oil tank. Unlike the MultiHeat or the wood boiler, these fully automatic boilers do not require a backup boiler and can be installed as the sole heat source for a house. We're excited about this technology and plan to install one of the first automatic pellet boilers in Maine in our own Portland workshop in 2009.

The automatic pellet boilers tend to be a bit more expensive than their bag fed siblings, but eliminate the cost of a backup boiler. We expect to be able to install them for between $20k and 25k. Automatic pellet boilers require bulk delivery, which is just coming on line this year with a number of different suppliers offering delivery into our largest Maine Cities; Bangor, Portland, Lewistion/Auburn, Rockland and Brunswick.



If you pursue either of the pellet boiler options, the solar domestic hot water system which we'd pair with it is a more conventional, dual coil tank with two or three collectors. This can be either evacuated tube or flat plates and both work very well. Typical cost of that installation might be $10-11k (less the 30% federal tax credit and possibly the state rebate of $1k).

System 4: Electric Heat powered with Grid tied Photovoltaics

Electric heat has a bad reputation, and mostly it deserves it. Electricity tends to be expensive and when you get it from the grid it is environmentally filthy. On the other hand, because a grid tied solar electric (photovoltaic) system allows you to generate renewable electricity during the long days of the sunny summer months and carry that credit forward to the winter heating season, electric heating systems can be one good way of achieving the goal of a home with truly zero carbon footprint.

Since electricity is an expensive, premium energy source, we always want to use it as efficiently as possible. One way to do this is with a **Ground Source Heat Pump**. Ground source heat pumps are also frequently called 'Geothermal Heat Pumps' though that name is a bit misleading as it leads people to associate it with hot springs and molten lava, neither of which you'll find under your property here in northern New England. In fact, the way a ground source heat pump works is to take advantage of the nearly constant 50 degree temperature in the soil and using a refrigeration cycle, to use that energy to heat your house. Doing this requires a substantial amount of electricity for circulating pumps and especially for the refrigeration compressor, which is why we categorize heat pumps under the heading 'electric heat' , because that is what it is. When you heat with a heat pump, you are essentially heating with electricity, though at an exceptionally high efficiency. The factor of efficiency over simple resistive electric heat is frequently expressed as a C.O.P., or the Coefficient of Performance. A heat pump with a COP of 3 uses electricity 3 times as efficiently as resistive electricity to produce the same amount of heat.

In Maine, each 1,000 watts (1kW) of installed capacity of grid-tied photovoltaics can produce roughly 1,350 kw-hr of electricity each year. If a heat pump is producing heat at a COP of 3, it means that each kW of PV provides enough electricity to make 14 Million BTUs for space heating.

This exceptionally well designed and built building is heated by an air source heat pump powered by a photovoltaic array.

The solar thermal system (in the center of the roof) provides hot water and does some of the base load heating for the space.

Ground source heat pumps powered by PV make sense when the load is fairly large and when there is also an air conditioning load (as the ground source heat pump handles air conditioning with a very high efficiency). Unfortunately, their performance is rather site specific and they tend to be expensive to install. If the total building's load is somewhat smaller another alternative to consider is an **air source heat pump**. Although they tend to have lower annual COP's compared to ground source heat pumps, they are also much less expensive to install.

A 1,500 sf house with 20,000 btu/sf/year heating requirement only needs 22 Million BTUs per year. An air source heat pump with a COP of just 2 would require less than 2,000 watts of PV to handle the heating load, and a 5,000 watt system should handle the entire energy budget of the home, at a cost of roughly $40,000 minus the 30% federal tax credit. A simple air source heat pump adds only $5-6 k.

An environmental aside about electric heat: Electricity is dirty. Even though heat pumps use electricity more efficiently, electricity is a dirtier fuel in terms of lbs. of CO2 emitted per BTU of energy delivered , even when put through a heat pump. In our opinion, heat pumps start to make environmental sense only when they are powered by renewable electricity. If you are going to buy filthy, fossil fuel derived grid electricity to power a heat pump for heat, you are better off burning the fuel yourself in a boiler or furnace and skipping all the complicated energy conversion steps in the process.

When the required backup heat load gets really small, either because the house is super tight, the homeowner decides to burn wood in a wood stove or because a solar themal system carries a substantial fraction of the heating load, the final option to consider for electric heat is good old fashioned **resistive electric heat**. This can either be a simple electric baseboard or panel radiators, or the heat can be delivered through a low temperature hydronic system like a radiant floor. These systems use an electric boiler which can be installed with a relatively low up front cost and are simple and reliable. Installed cost for the boiler tends to be between $5 and 7k. The PV system cost varies according to size, but tends to be between $8 and 9 per installed watt (minus the federal tax credit and any available state incentive).

This super insulated and beautiful home, built in Woolwich, ME, relies primarily on a wood cook- stove for heat during the winter.
A ReVision Energy solar thermal system provides domestic hot water and some heat to the radiant floor, while the balance of the heat is provided by an electric boiler powered by the awning mounted solar electric system, which is also strategically located to provide passive shading to the building in the summer.

Any of the above electric based renewable space heating options can be combined with a solar thermal system. At the very least, the thermal system should be sized to carry the majority of the domestic hot water load, but very frequently, the system is actually somewhat larger and contributes to the space heating load in the shoulder seasons (spring and fall) so that the electric backup can be smaller and used less often. We'd be happy to discuss the optimum combination of solar thermal and PV powered electric heat for your particular home.