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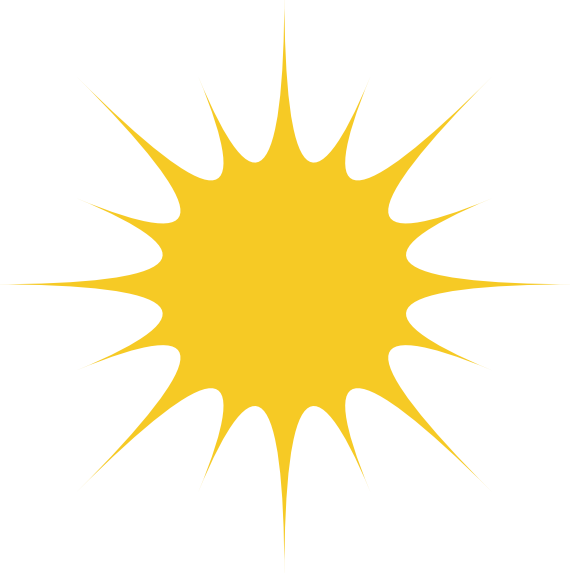

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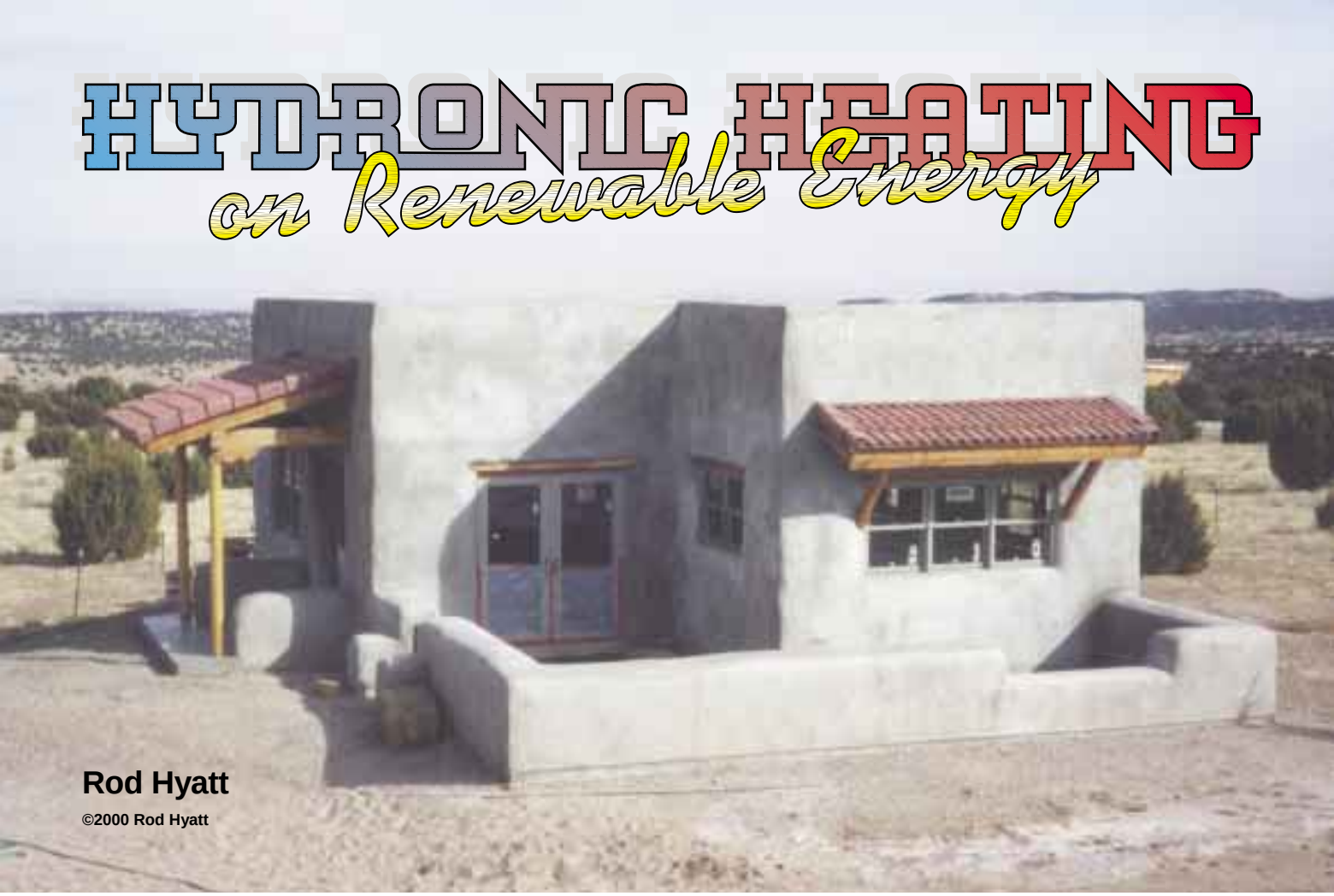
HYDRONIC HEATING on Renewable Energy



Rod Hyatt

The Edisons' 800 square foot (74 m²) studio is made of straw bales that have been stuccoed. Like the main house, the studio is solar-hydronically heated.

Off the grid and can't power the pumps and controls for a heating system? Yes, you can. The answer is DC hydronic heating—a natural extension of using the sun's energy in your energy-conscious home.

One of the most overlooked aspects of solar energy is hydronic heating, which you might have heard called radiant floor heating. The concept is simple, and a must for any solar-powered home. Hydronic heating works by circulating heated water through or under your floors. This can be easily integrated into the construction of a new home, or installed in an existing home. Many systems can be installed by the homeowner. Add solar hot water panels, and the sun will help you heat your home.

Forced-air heat is often not suitable for off-grid homes because the power consumption is far too high. And conventional radiant floor heating systems are generally not suitable because of the large amounts of electricity the pumps guzzle. The answer is low voltage DC pumps.

There are other advantages to these systems for homes on and off the grid. Top among them is the reduction in dust and dry skin, which are problems caused by forced-air heating systems. Also, an efficient system can use up to 40 percent less fuel, according to the National Energy Association. And you just can't beat a cool evening spent watching TV lying on the warm floor under a blanket, or stepping out of the shower onto a heated floor.

The straw bale studio in progress.

Hydronic Loops Under a Wood-Framed Floor

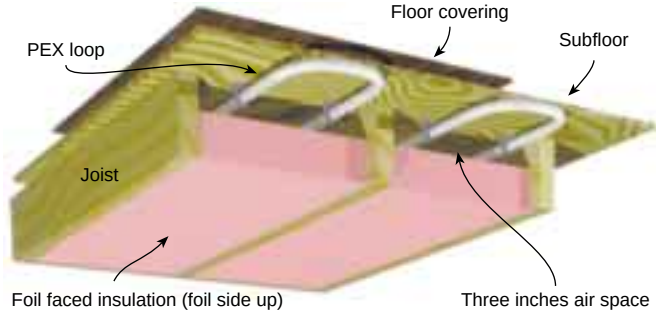


Image courtesy of Wirsbo.

Hydronic Loops In a Slab Floor

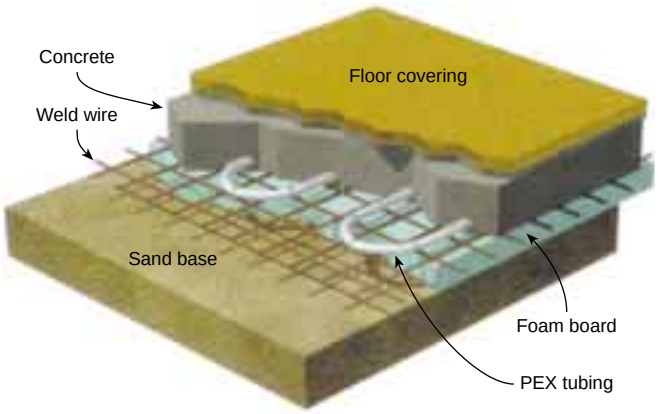


Image courtesy of Wirsbo.

We've heated our basement with radiant floor heat for several years now. Not only does it make our bottom-floor family room and office comfortable, but it reduces the need for heating on our main floor.

As a designer of low-voltage DC hydronic floor heating systems, I've worked with people in all walks of life. They come to me with a variety of budgets, whether building their dream home or restoring a 30 year old monstrosity (like mine!). Hydronic heating can be used in nearly all homes. Outside, it can even be used to thaw icy driveways.

Three Main Uses

I've found that there are three main applications for hydronic heating systems. First is new construction. At this stage, the heating system can be custom designed for your house.

Second is retrofitting existing homes. This can be an easy or difficult undertaking, depending on the style of the home. The homes best suited for this have crawl spaces or unfinished basements. We've found that the cost of these systems can be comparable to forced-air heating. So it becomes a viable option for a city or suburban home that depends on the local electrical utility.

Third is retrofitting a hydronic heating system into an existing solar-powered home. Often, a conventional hydronic heating system uses too much energy to operate on a solar-electric system. However, DC-powered pumps—and the fact that many AC components aren't needed—can bring a hydronic heating system within the power boundaries of an independently powered home.

Recommended Pump

Hydronic systems can be designed with very low power requirements. In the systems I've designed, the heart of the system is the El-SID (static impeller drive) pump manufactured by Ivan Labs of Jupiter, Florida. These pump motors, which come in 3.5, 5, and 10 watt sizes,

When it's finished, this 4,800 square foot (445 m^2) straw bale structure will be the Edisons' dream home.

The Edisons' home, waiting for concrete to be poured. PEX tubing is tied to the weld wire to hold it in place during the pour.

have no moving parts. The pump has an inductive magnetic drive that magnetically spins the propeller in the pump. Because there are no seals or moving parts in the motor, it has an extremely long life and makes no noise. These DC-powered, low-voltage pumps can be operated directly from your home's thermostat. No other controls are needed.

Normally, an inverter is required to change battery (DC) power to AC home power. With this DC system, the inverter does not have to be sized to run the heating system. As a result, it works well as an addition to systems that don't have inverters. Or if you have an inverter, you won't have to upgrade to a larger inverter. Because it's a DC system, it can operate directly from your batteries. In a grid-powered home, a simple AC/DC wall cube makes a great power source for these pumps.

Each 10 watt pump has the capacity to circulate hot water through 600 feet (180 m) of half inch (13 mm) tubing. I recommend PEX (cross-linked polyethylene) tubing. PEX is fast becoming an industry standard because of its successful track record in Europe.

The size of the system depends, of course, on your climate and the size and type of your home. The entire operating system for most homes consists of a DC power source, as well as a number of 10 watt El-SID pumps turned on and off directly by a thermostat. The pump and thermostats are the only moving and electrical parts in the entire system.

Sizing Your System

Here's how to figure what you will need for your home in an average climate. Consideration of your climate and BTU heat loss calculation could increase or decrease these figures. These are approximate examples only.

First, figure out how much tubing your home will need. A good formula is 125 percent of the square footage of the floor area you want to heat. A 1,200 square foot (110 m^2) home, for instance, would need 1,500 lineal feet (460 m) of tubing. PEX tubing is best used in lengths of 250 feet (75 m). In these low temperature systems (they generally run at temperatures of 100–120°F; 38–49°C), heat duration peaks at 250 feet. So by the time the water's gone much more than 300 feet (90 m), it has expended its heat.

By stamping and staining the concrete, the Edisons have eliminated the need for any floor covering. You'd never know there were heating tubes underneath.

A single El-SID pump will support two loops of 250 feet each. For example, a 1,200 square foot home will need 1,500 feet of PEX, and will require a total of three pumps and six 250 foot loops.

Tubing & Insulation

During construction of a home, the tubing can be installed directly in an insulated concrete slab floor. An insulated slab is a concrete floor that usually has about 2 inches (5 cm) of rigid foam board under it, and a thermal break around the edges. Often, we put 2 inch foam board right down on a prepared dirt or sand bed.

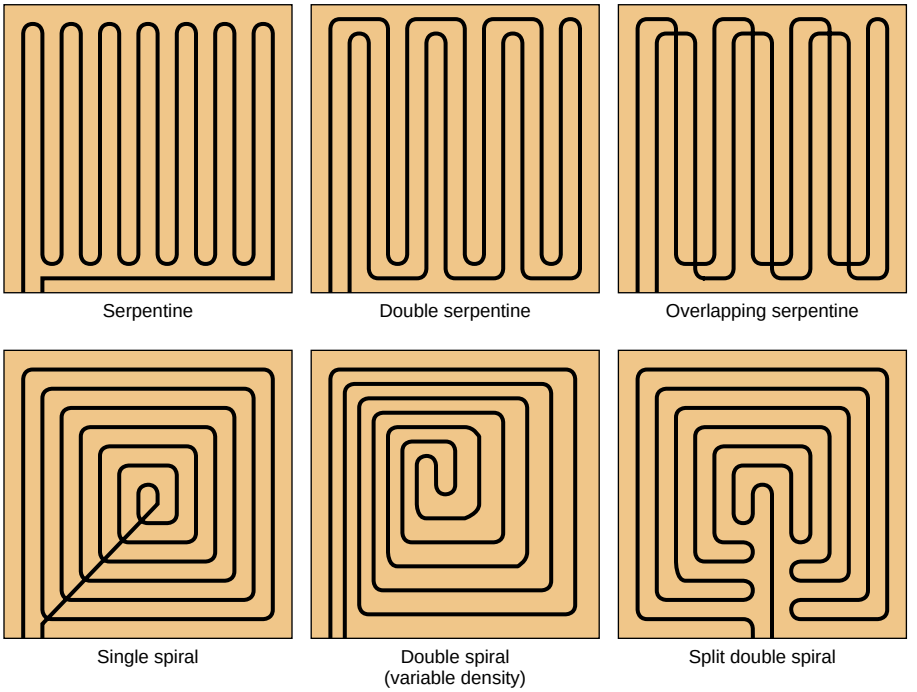
I often use 6 by 6 inch (15 x 15 cm) weld wire to meet the metal requirements of the floor. This works well in hydronic systems, since the weld wire makes an excellent structure to attach the PEX tubing to.

A well insulated home in an average climate will require the tubing runs to be spaced about 10 inches (25 cm) apart. After the tubing has been fastened to the weld wire, the standard concrete floor is finished right over the tubing. Concrete depth is usually 4 inches (10 cm), with the tubing laid approximately in the center of the slab's depth. You have several options as to what pattern to run the tubing (see diagrams below).

For standard wood-framed floors, the tubing can be tacked right to the underside of the floor between the floor joists or TGIs. Generally, two runs (one loop) of PEX tubing are attached to the underside of the floor between each floor joist. Once the PEX is installed, insulate the cavity with a foil-faced insulation.

A tangle of tubes come together at the location of the future manifold in the main house.

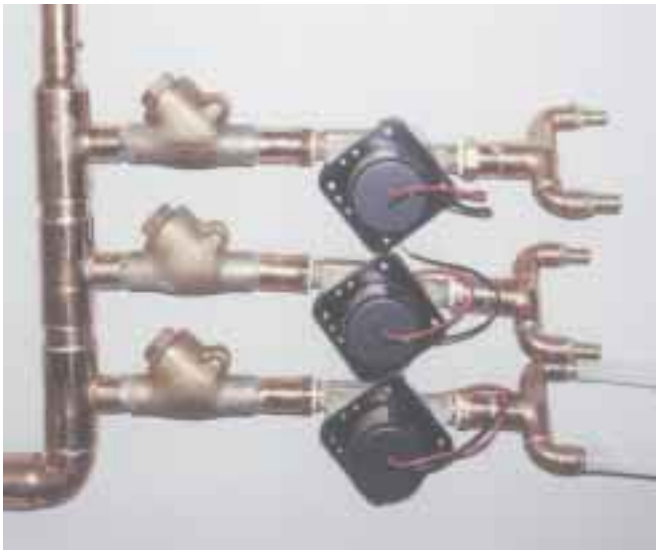
Suggested Loop Patterns



Face the foil up, leaving a 3 inch (7.6 cm) air space between the top insulation foil and the underside of the floor. This works to reflect the heat back up through the floor. The PEX tubing should not touch the insulation. It's not necessary that the PEX be in direct contact everywhere on the underside of the floor; part of the heat transfer takes place by heating this 3 inch air cavity.

Concrete is most often used for radiant heating systems, especially in construction in the United States, and a layer is often poured right over wood floors. Its value is in its ability to retain warmth, although it does have a slow reaction time. On the other hand, the response time of radiant systems placed under wood floors is much faster.

Tubes gathered and ready for a manifold.



Static impeller drive (SID) pumps from Ivan Labs are the secret to the low wattage of the studio's hydronic radiant-floor system.

And because wood floors are on main and upper levels where the sun shines and heating needs change more often, the quicker response is a benefit. (A concrete mass works great in the basement where you want a slow, even heat.) Combine the quicker reaction time with the relative simplicity of installation and the cost savings, and the benefits of installing a system right under an existing floor can even out with those offered in a concrete-poured system.

Building the Manifold

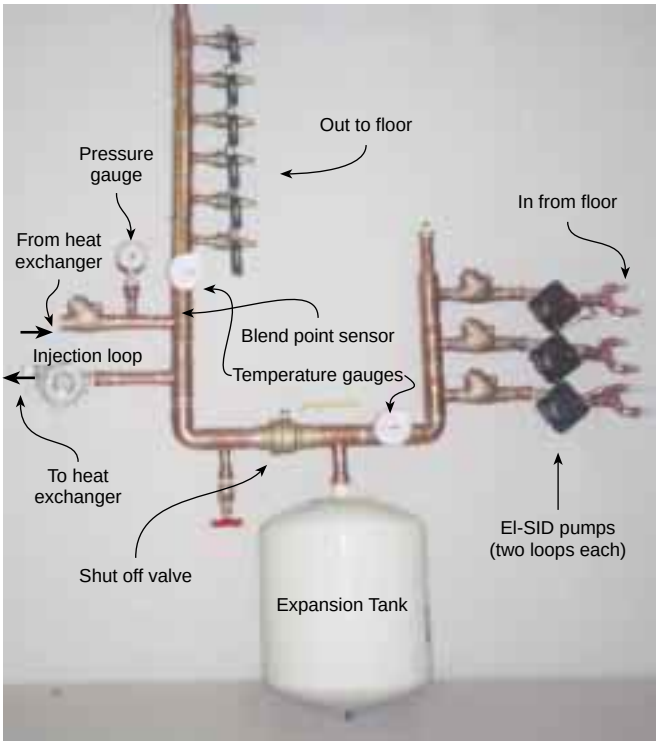
The next step is the creation of a simple manifold. A manifold is a feed and return junction that delivers an even flow of warm water to and from the floor loops. They are often built out of 1-1/4 or 1-1/2 inch copper tube fittings. They can be custom built to accommodate the pumps and connect all the feed and returns of the PEX loops. Each pump (with two loops) can be operated as one zone.

We like to use an injection loop and pump. This is a wonderful way to turn your passive solar-heated rooms into giant solar collectors. For example, consider a two-story home with large south-facing windows on the main floor. The sun shines on the floor all day long. The warm water from the sun-heated floor will circulate to the cooler places and basement.

The injection loop pump will not inject heat into the system until the system's temperature drops to a particular setpoint. With the sun shining and warming this portion of floor, it may supply enough heat to maintain the temperature of the entire house (see manifold photo with injection loop).

The injection pump consists of an El-SID pump that's similar to a zone pump, but has a built-in controller. There are also two sensors. One is placed on the manifold just below the injection-loop blend point, where it monitors the system's temperature and determines when to turn the pump on and off. The other is placed outside, usually under the north eave of the home. It monitors the outside temperature, giving the

An example of a DC manifold with three zones.



indoor system a heads-up of outdoor temperature changes, like those caused by the rising sun. This system of injection pump and sensors is often called an outside reset.

The manifold is relatively easy to construct, but can be time consuming. Often we build the manifolds for the customer's particular home. When the manifold is complete, we attach the PEX loops to the manifold and hook up the heat source. Voila! Warm, clean, quiet heat.

Where to Find Heat

Heat can be supplied by a direct gas-fired boiler. A tank with a heat exchanger can heat the home, as well as supply all the domestic hot water you need. Hot water solar panels are an excellent asset for this system, and can supply heat for both the home and for domestic water. Another option for a heat source is a wood/coal-fired boiler. Some systems, like the one I use in my own home, use all three. The heating system can be installed by homeowners who have basic plumbing skills.

Avoid Cast Iron

When plumbing and heating contractors install radiant floor heating systems, they have a difficult time not using cast iron boilers and pumps. However, cast iron is thick and heavy, and it rusts as it ages. Yes, you can purchase more expensive specialty components (like oxygen-barrier tubing) to slow this process. But the cast iron will still decay and send all that rust through your heating system.

Can you imagine all that gunk and abrasive rust circulating through your pumps, valves, and tanks? The goal is to install a clean radiant heating system that will last forever. The best choices are stainless steel, copper, PEX, and brass.

Boilers are most often cast iron, but I prefer boilers that are made of nonferrous metals. Cast iron boilers were once the only choice. But copper and stainless steel boilers are becoming more readily available. Their efficiency ratings range from 80 to 98 percent.

Radiant Heating in the Rockies

Last spring, I was contacted by Richard and Maura Edison, a young professional couple in Boulder, Colorado. They asked me to design a solar hot water and radiant floor heating system for their new 4,800 square foot (445 m^2) home and 800 square foot (74 m^2) studio, which are both straw bale. They started their dream years ago by purchasing 100 beautiful acres in southern Colorado, west of Pueblo.

Maura Edison came up with the floor plan of the home and studio. The heart of the power system would be a

Edison Studio Heating System Costs

#	*Component*	*Cost (US$)*
1	Aquastar 125LPL recirculating boiler	$695
	1,000 feet 1/2 inch PEX tubing	480
2	El-SID 10B pump, 12 V 10 W	378
1	March 809-BR-HS-12 pump, 12 V 40 W	239
1	15 gallon insulated water tank	129
1	Amtrol expansion tank, with liner	95
1	Mixing valve for domestic hot water	95
12	1-1/4 x 3/4 x 1-1/4 inch copper tee*	84
1	Crimping tool	50
1	Honeywell Aquastat (submersible thermostat)	49
2	Check valves, swing type*	42
1	Thermostat	39
2	Temperature gauge	38
4	3/4 inch ball valves, full-port*	28
10	3/4 inch sweat to 1/2 inch female thread*	20
2	Air purge with key*	20
	5 feet of 1-1/4 inch tubing*	20
1	Pressure gauge	13
2	1-1/4 inch copper street elbow*	10
8	1/2 inch Pex to 3/4 inch sweat/barb*	8
4	1/2 inch street elbow*	8
1	Filling spigot*	8
2	1/2 x 3/4 x 1/2 inch tee*	6
2	1-1/4 inch to 1/2 inch reducer*	6
2	1/2 inch female sweat to threaded*	4
	Engineering	0
	Tech support	0
	Total	$2,564

*Manifold components

Trace PP 5548D double inverter power panel, with a dedicated, battery-direct 1,000 watt 48 volt Exeltech inverter to run their finest electronics.

The Edisons had studied up on all the solar hot water panels available, and had come to the fast conclusion that the best on the market was produced by Thermomax. After working with a number of systems, I have also found Thermomax to be the highest producing and best quality product on the market. The evacuated heat tube technology has the highest heat collecting abilities per square foot of any system on the market. Each collector is 80 by 87 inches (203 x 221 cm), and contains 30 tubes.

Eight Thermomax panels, with thirty evacuated tubes each, generate hot water for space heat and DHW.

Finding the space to place the eight Thermomax panels on the roof was not a problem at all. And because each Thermomax panel only holds about 1 liter (about a quart) of water, there was no concern about weight in the roof design.

The system design called for the heat to be sent to a 120 gallon (450 l) storage tank via an internal heat exchanger. The heat would then be dispensed to the different floor zones as it was called for. The Edisons have not decided where they will send the excess heat available in the summertime. I suggested a large hot tub or pool.

Paul Huber at EcoStruct was contracted to build this home and studio. After he took on the job, Paul called me to fax the floor plans. My fax machine spit out seven pieces of paper, each a different segment of the house and studio. It took me an hour to tape all the pieces together to make a floor plan.

It was the most ingenious floor plan I had ever seen. The exterior walls had a total of 28 corners. I was getting dizzy just thinking of stacking the bales up on such a labyrinth. I could see that it would take an extremely talented builder to complete such a wonder. There was no doubt that the result would be a fantastic beauty, as you can see in the photo of the nearly completed studio.

The hydronic heating system for the studio has a very simple one-zone, one-thermostat operation that will also provide domestic hot water. The power demands are so low that very little consideration needs to be taken in sizing the home's power system. Because it is all DC, an inverter has no part in this plan.

There have been many studies on straw bale wall construction and its insulation value. One University of California study estimated that a standard 18 inch (46 cm) wide straw or rice bale equals R-26. Research by Joe McCabe at the University of Arizona with the same size bale found an insulation value of R-42.8.

Because there are many variables, such as the moisture content of the bales, it's difficult to determine the building's heat loss and come up with an accurate pump run time. I estimated that the pumps will run for an average of six hours in each 24 hour day. That would give a total power load of 390 watt-hours per day. You can burn up more power watching TV than it takes to run this heating system.

The home will have a much larger and somewhat more complex heating system. But the point is, you don't need a lot of power to support it, and you can have a wonderfully heated home using renewable energy.

Comfortable Radiant Heat

With a well-designed DC-powered radiant floor heating system, you can now have all the comforts with no sacrifice. Construction costs are kept down because there's no sheetrocking around big air ducts. And the price tag is not much different than that of a dust-blowing octopus in your home. Besides, who wants all those holes in the floors and walls anyway?

Access

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Dr. F. Mahjouri, Thermomax Technologies, 5560 Starrett Pl., Suite 115, Columbia, MD 21044 • 410-997-0778 Fax: 410-997-0779 • usa@thermomax.com www.thermomax.com

Richard and Maura Edison have a Web site about their straw bale house: http://members.aol.com/rcedison2

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four color on negatives