On-Farm Energy Case Study
Log Wood Gasification and Hydronic Heat for Greenhouses and Farmstead
Vermont Herb and Salad Company - Benson, VT

Heather and Jared McDermott are owner/operators of Vermont Herb and Salad Company in southwestern Vermont. They grow organic salad greens, spinach and culinary herbs that are marketed to regional distributors, grocery stores, and some restaurants.

Their farm is 100 acres, with about 80 acres in woodland. There are two 30' x 90' heated greenhouses that are used for starting seedlings and winter greens production, as well as four 30' x 100' unheated greenhouses used for in-season production of leafy greens. There is a 500 sq. foot packing house, a 1000 sq. foot storage area, and a residence just under 2000 sq. feet in size. All heated areas are now fueled by wood from the farm's woodlot.

At the core of the heating system is a Sequoia Paradise model E3400 outdoor wood furnace. It has a 320,000 Btu/hr rating, with a forced downdraft gasification design. The firebox is 44" deep x 48" tall x 32" wide, holding 39 cubic feet of fuel. The unit stands 60" wide x 72" long x 94" tall, has fiberglass insulation and holds 210 gallons of water. (Sequoyah Paradise, Mauston WI, www.wdheat.com/index.htm). The purchase price was $11,500.

Before installing the furnace and the rest of the heating system, the McDermotts renovated the old dairy barn on the property, which is adjacent to the heated greenhouses and also holds the storage and packing areas. Renovation included pouring a new concrete floor at ground level, for about $4,000, and making improvements for better accessibility and handling cord wood such as installation of a garage door.

The furnace is located inside the renovated barn and is vented outside with metal-bestos pipe; as it would be in a conventional basement installation to heat a big house. “What we initially did after that is a little unique.” says Jared, “We connected the unpressurized hot water in the furnace to a set of large tanks, which then collect and exchange heat with a pressurized hot water system. The pressurized system delivers hot water to our greenhouses, packing area, and home, where it is released by air-to-air heat exchangers or radiant floor heat.”

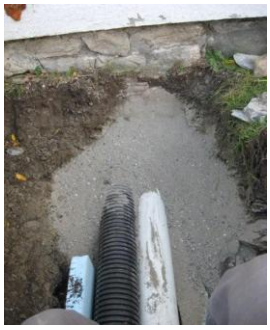
The 215 gallon water reservoir of the furnace was plumbed into 4 unpressured 275-gallon steel tanks totaling 1,100 gallons of hot water storage. All the tanks were connected, so they were really one large thermo-accumulator, allowing the furnace to run all day long even when the greenhouses are not calling for heat.

Initial system with tanks

Revised system with tanks replaced by heat exchangers.

“We initially thought we wanted around 1000 gallons of water to accumulate heat for a 300,000 Btu/hr system. But that turned out to be a bad move. When heating is needed, the houses need it most of the time. Additionally, we found that the volume of hot water storage was not enough to really provide adequate overnight heating. The desire to store hot water during the day eroded our ability to simultaneously heat the houses early in the morning and early in the evening when the sun went down. So we ended up taking the hot water storage tanks out all together. In place of them we now have two heat exchangers ($350 each) which serve to connect the low and high pressure systems. We load the fire box at the end of the day and it carries the load through the night.”

The pressurized, heated water is then delivered to different heating zones through insulated Pex tubing. The diameter of the Pex tubing varies depending on the amount of heating that is needed: 1.25-inch tubing runs to the greenhouses, 1-inch to the residence, and 0.5-inch to the packaging facility.



“We built the piping system ourselves since insulated Pex tubing was back-ordered and we didn’t want to wait. We used regular Pex for the unpressurized side, but purchased Pex with an oxygen barrier for the pressurized side of the system to reduce the amount of air getting into the system which could cause corrosion. Then we used R-10 foil wrap to cover each pipe individually. That provided a thermal break between the two pipes, to separate the hot and colder water and avoid any heat exchange.

“We wrapped the two pipes together with R-20 foil wrap and slid them inside 4-inch drain pipe. That was easier than I thought, but wrapping the Pex itself was a challenge since it isn’t flexible when it is cold. All the pipe was then buried 3 to 4 feet deep and enclosed in 2 inch blueboard (R8). So far, we’ve had no noticeable temperature drop in the 100 feet of distance from the tanks to the house, which is the longest run. ”

Two Dayton 104,000 Btu/hr water-to-air heat exchangers release heat into each of the greenhouses. They have 1/3 hp motors running the fans, and cost $600 each. Unlike combustion heaters, they can run continuously without problem, so their relatively low Btu/hr rating for a 2500 sq foot greenhouse is a bit deceptive. The heat exchangers run off programmable thermostats that can be set for different nighttime and daytime temperatures.

“So far, in both greenhouses we can easily maintain 40 to 50 degrees above outside air temps. For our crops under low light condition, we need to maintain 50 to 55 degrees as a minimum air temperature. We don’t really want a lot of heat during the winter because the crops just stretch and get small leaves, but more heat once in a while does help reduce humidity to manage diseases. Before we turn on the furnace at night, the humidity can be about 95%, then it goes down to 55% after the system runs all night. We do have an older 150,000 Btu/hr oil backup furnaces in one of the greenhouses, just for emergency purposes.”

“We also have some bench heating. When we replaced a roof on a barn several years ago, we salvaged the old metal roofing from it. This makes a nice sheet under our radiant bench heating system. It allows water to drain off, but also acts as a radiant reflector to direct the heat to the plants. This system works until about 10-15 °F outside temps and then we need the forced air system.”

"In our home we already had a hot water system heating system, so we plumbed straight into the existing system. We did the same thing in the packing house, where we had radiant floor heat; we just removed the heater and connected to the new system."

Jared in front of one of his home-made bench heaters made with salvaged metal roofing and PEX tubing.

"To move water around in our system we chose Grundfos multi-speed 1/10 horsepower circulator pumps (http://www.grundfos.com/web/homeus.nsf). There are two pumps feeding the tanks from the furnace, then each of the three water-to-water heat exchangers has an unpressurized pump feeding it. On the pressurized side, each tank has a circulator pump feeding its zone, so there are eight pumps in total. Because they are multispeed you can adjust for the demand of each heating each zone. These pumps can go from 9 gallons a minute to 30 gallons a minute so they provide a lot of flexibility."

Grundfos multi-speed pumps. The switch on the center left of the black cover allows selection of one of thee motor speeds resulting in variation of the flow.

"One benefit to the unpressurized side is that it can never get too hot; it would just boil over. I tried turning up the aquastat to 190 degrees, but with no real benefit; the tanks didn't get a lot hotter, like 180 degrees, and stay there. With the aquastat set at 175 degrees the tanks run at 150 to 170 degrees. Turning up the system just seems to use more wood without heating the water up a lot."

"It was sort of surprising that our water temperatures run a little cooler that you would want in a commercial oil or propane hot water system. We can deal with that because we bought large heat exchangers, so we if we need to move a little more water through the system to get the same amount of heat released, that's OK. We basically have an endless supply of 150 to 170 degree water."

One of the main reasons we decided to put this system in is that we have access to wood on our own property. We recently acquired a neighboring sugarbush of about 80 acres, and it hasn't been managed in 40 or 50 years, so there's a lot of wood to be removed for many years. We already have the equipment like a big tractor, chainsaws and such, and we have family and friends that have experience in the woods as loggers or tree service people – it does take skill, you don't just go cut wood. So we put a crew together this summer and got about 30 cords organized in the landing area in 4 days. If I had to guess, it might cost us $50 per cord with all our expenses. If we needed to, we could also buy truckloads of logs for about $16/cord locally, and then process them."

"There is no such thing as seasoned, dry wood when it is left outside. So we have converted an old hay barn to be our wood shed. We store 30 cord in the barn and get it bone dry in 9 months. The barn has excellent access for tractors: Our goal is to never lay a hand on the wood."

"We have a forklift, so we bring the logs right down to the furnace area; with the concrete floor in the old barn we can drive right inside so we aren't out in the elements trying to process the wood or load the furnace. We cut everything to about 80 inches so it only needs to be cut once more; we don't need to split it to load the furnace because it has such a large box."

"When we were researching furnaces there were a couple of other units we liked, but they all had pretty small wood boxes. Tarm systems had a good reputation, Wood Gun had some really nice central heating systems, and Blue Forge also looked interesting. They were all in the same price range, but they all had small wood boxes; the one we got has a wood box-- and a door-- about twice the size. I've heated with wood a long time and knew that I did not want to become a slave to feeding the furnace; that was an important factor. The idea is to load up once or twice a day; we do not need to load in the middle of the night. When it's really cold we can still load every 12 hours. Since it does have a big burn box it does use a lot of wood when it's cold out, about half a cord a day. When it's in the 30s to 40 outside we only load up a little in the morning and then load up more at night to conserve on wood use. "

"We went into this project thinking we could easily modulate the heat to meet our load by using the hot water storage tanks as a buffer. It turns out it is probably easier to modulate your load (i.e. which houses are heated when) to keep your wood boiler running at it's peak as long as possible. We're adding a third heated house this coming heating season at strategic times to keep the boiler running hard, where it likes to be."

"The furnace is so big and burns so hot that you don't need to relight it, even after 12-16 hours you can still throw some small branches in and turn on the forced draft fan and it relights. But wood is not oil; oil is easy. It may cost a lot but you just write a check and a guy pulls up in a truck and delivers millions of Btu's to your property and the heat comes on without you even knowing it. We have a lot of wood in Vermont, but it may not be practical for most people."

"The total cost of our system was about $30,000--not including improvements that made life easier like a concrete floor and a walk-in basement interior. We also paid a lot for metal items, since copper and steel were at all-time highs when we did this project. There were several thousand dollars in copper and steel fittings. There was a couple thousand dollars in Pex tubing and several thousand dollars in plumbing supplies. We also overbuilt the system in some ways but that's better than wishing you had done it differently later on."

"We are a small business, and controlling our heating costs was important. This system gives us a lot more flexibility; we can pay ourselves to maintain our forest while we're collecting our fuel. Plus the cost of buying oil at unpredictable prices can be backbreaking, especially in winter when our cash flow is less. We'd easily be using 1200 gallons of oil each month throughout the 4 months of winter without this system. So at $3.00 a gallon we'd be spending $3600 a month whereas now we're using about half a cord a day or $750 of wood a month. From mid-October to mid-November and mid-March to mid-April we use half as much fuel, so overall we're saving about $14,000 a year in fuel costs."

"We did get some help from grants to cover our costs, and we did a lot of the research ourselves, but we worked with a master plumber and engineer who helped us with our design. We purchased a lot of product from his business so he looked over our plans before we installed anything."

- Vern Grubinger, 12/2/08
-revised, Chris Callahan 7/11/10