Project Report

Investigating the Challenges to Heating Several Greenhouses from a Single Wood Pellet Boiler and the Most Energy Efficient Installation System

David Marchant and Jane Sorensen, Riverberry Farm, Fairfax, VT

By Chris Callahan, University of Vermont Extension, November 2013

INTRODUCTION & PURPOSE

The goals of this project were to explore the challenges associated with the heating of multiple greenhouses in a relatively small-scale, diversified vegetable operation and to report on these findings along with energy efficiency conclusions.

The project involved the installation of a 250,000 BTU/hr (input) multi-fuel solid biomass boiler (SN 201108, produced 2/2011). The boiler output is modulated from 0 to 212,453 BTU/hr and is rated with an average efficiency of 87.8% (LHV basis). This boiler is qualified under the EPA Hydronic Heater Phase II Program. The unit purchased and installed was a Central Boiler Maxim M250, and it is intended to support the heating of two greenhouses side by side. These greenhouses are 27'x75' inflated double poly construction and are used for the production of tomatoes, bedding plants, and greens from early spring to mid-summer.

David has had prior experience using an LDJ A-Maize-ing Furnace (165,000 BTU/hr input) with better reliability and performance than most. However those units lack automated ignition and heat modulation. Additionally, the venting of the unit's exhaust tended to be problematic resulting in reduced reliability. This was most notable on days with variable cloud cover and mild temperatures which challenged the natural draft system. While David still uses this smaller unit in another house, he remains interested in increased adoption of propane alternatives for greenhouse heating and the Maxim unit offered an opportunity for improvement.

DESIGN & INSTALLATION

The Maxim boiler was installed, along with a small fuel bin, on the eastern side of the north house. This location allows for relative easy fuel delivery near the bin and minimizes the run of the main underground insulated piping to and from the boiler to reduce heat loss.

There are several options available for insulated underground PEX tubing which vary by insulation value, design, and price. Guidance from other growers who have opted for the less expensive insulated tubing was to purchase the more expensive option. The main reason is that the heat loss to the ground is less. The main reasons suggested are the reduced insulation value of the less expensive option and the potential accumulation of water in the open space that exists in that design.

Figure 1 –A less expensive underground insulated PEX tubing option (left) is wrapped in foiled bubble wrap and has space between the insulation on the pipe as well as the outer wall. Cost is approximately $7.00/ft. The solid EPS insulated PEX tube (right) is more expensive at $11.00/ft but has demonstrated reduced heat loss and pipe to pipe heat transfer. Water infiltration is a concern on the foil wrapped version on the left due to the open area that exists.

David was interested in supply heat in several ways to the two greenhouses; (a) air heating, (b) ground or root zone heating, and (c) bench mat heating. This required a plumbing manifold and distribution plan. This was created jointly with Chris Callahan (Callahan Engineering).

Figure 2 - The photo shows the main manifold being constructed (LEFT) and finished (RIGHT). Note the insulated supply/return PEX (lower right) which is connected to the boiler and (far right) to the south house. This manifold is needed to distribute the hot water to the different forms of heat input used in the two houses.

Figure 3 - Air heaters are used to convert the hot water to hot air for space heating in the greenhouse. They consist and a radiator and a fan (left). On the right side of this photo the insulated supply/return PEX can also be seen. This was used for longer runs underground from the boiler to the north house and from the north house to the south house.

Figure 4 - PEX tubing was buried 12-16" underground in the north house for root-zone heating of tomatoes. Dave has noted a significant boost in early growth as a result of putting heat into the ground near the root zone of this crop.

Figure 5 - Tomatoes being grown in the north house after installation of the ground heat.

Figure 6 – The water flow to and from the boiler is via insulated underground PEX tubing seen in the lower right corner of this photo. The panel has been removed from the control box to show the propane start/backup burner controls and auger controls. The boiler was plumbed to a main manifold that is in the north greenhouse. From this main manifold the hot water can be sent to (a) an air heater in the north house, (b) in ground heating in the north house, (c) an air heater in the south house, or (d) bench heating mats in the south house. The control of the hot water distribution is both manual (valves) on a seasonal basis and automatic (thermostat) once the sub-system has been enabled for the season.

COSTS AND BENEFITS

The boiler cost was $8,030, with a total installed cost of $16,388. David purchased the unit from Paul Boivin (Vermont Golden Harvest, Addison, VT) who is a Central Boiler dealer and a corn fuel dealer. The installation included a significant amount of plumbing that a furnace would not (since the boiler is based on hot water heating) and because of the desire to use the hot water in several different heat distribution methods. Some of this plumbing was also related to the use of the single boiler by two houses necessitating some interconnect plumbing. Regardless, with both wood pellets and fuel corn at $250/ton any propane cost above $1.44/gal will result in some savings when using the biomass boiler. With propane at $4/gal, the simple payback period is roughly 15 years.

There are other benefits besides the economics. The net CO_2 equivalent and criteria air pollutant emissions avoided based on David's actual fuel use from the 2012 growing season are presented below.

Fuel Burned	Equivalent BTU
Corn: 3,840 lbs @ 6,800 BTU/lb	26.1 Million BTU
Wood Pellets: 2,000 lbs @ 8,200 BTU/lb	16.4 Million BTU
TOTAL	**42.5 Million BTU**

42.5 Million BTU's worth of corn and pellets is roughly equivalent to 461 gallons of propane (@ 92,000 BTU/gal).

We used the COMET CO2/GHG calculator to determine the overall environmental impact of the displaced propane (http://cometfarm.nrel.colostate.edu/QuickEnergy) on this project. David avoided about 5910 lbs of net CO_2 equivalent. We then used the EPA GHG equivalence calculator (http://www.epa.gov/cleanenergy/energy-resources/calculator.html) to determine what this means in real terms. For example, 5910 lbs of CO_2 equivalent equates to about 5,000 miles of passenger car miles each year or 0.5 acres of pine forest.

While the net CO_2 and greenhouse gas avoidance is obviously a benefit of the biomass combustion, we were initially concerned about the criteria air pollutants (SO_2 and NO_x). COMET indicates the 42.5 million BTU of propane generates 4.66 lbs of SO_2 and NO_x combined. According to the EPA Phase II qualification report on the Maxim 250, it generates 0.06 lb/million BTU of pellets, meaning it generates only 2.55 lbs of combined air pollutants. Data on corn as a fuel is not published as a result of the EPA testing, but we do not think it will vary much from the pellet testing. The somewhat surprising bottom line is that criteria air pollutants were reduced as a result of this project as well.

LESSONS LEARNED

As a result of this project, the following key lessons were learned and are documented here for others to benefit from;

1. Adoption of a single boiler for partial heating of two adjacent greenhouses is feasible and best accomplished using a design that incorporates automatic ignition of the solid fuel and has the capability to modulate the firing rate.
2. The use of solidly insulated (EPS, etc) PEX tubing for underground runs of plumbing is highly recommended despite the higher initial cost.
3. This system includes some complexity that could be avoided if growers were interested in single heat distribution methods is each house. For example, if only interested in air heating, the main plumbing manifold could be simplified to plumb the boiler supply and return directly to the hot water coil / fan unit. Obviously, if ground heating is not desired a majority of the PEX tubing could be removed from the system reducing the complexity of the manifold and the overall plumbing costs. These multiple options were included in the system to demonstrate their use and to learn from the demonstration.

4. A simple payback is estimated to be 15 years with solid fuels at $250/ton and propane at $4/gal. Payback is based on approximately 3 months of seasonal use and relatively high propane pricing. Extended seasonal operation would reduce the payback period and reduced propane costs will extend the payback period.

OUTREACH AND EDUCATION

Vern Grubinger and David held a twilight meeting at the farm on April 18, 2012, which provided an opportunity for about 6 other growers to come and see the various biomass heating approaches David has taken. There was a lot of interest in the Maxim project and having had at least a partial heating season of experience David is pleased with the result so far. Riveryberry also hosted the NOFA-VT/UVM Extension Greenhouse / Tunnel Tour on April 3, 2013 which brought 36 attendees to the farm to learn about the farm's approach to greenhouse envelopes and biomass heating.

We are grateful for Agency support on this project and our greenhouse projects in general. We're hearing from other growers that there is continued interest in displacing propane and this is a unit that will make that more possible for everyone.